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ART. XIII.—*On the effects of Magnetization in changing the Dimensions of Iron and Steel bars, and in increasing the Interior Capacity of Hollow Iron Cylinders;* by ALFRED M. MAYER, Ph.D., Professor of Physics in the Stevens Institute of Technology.

PART II.

(Read before the National Academy of Sciences, in Cambridge, Nov. 22, 1872.)

On the Elongations and Retractions of Rods of Iron and Steel on their Magnetization and Demagnetization.

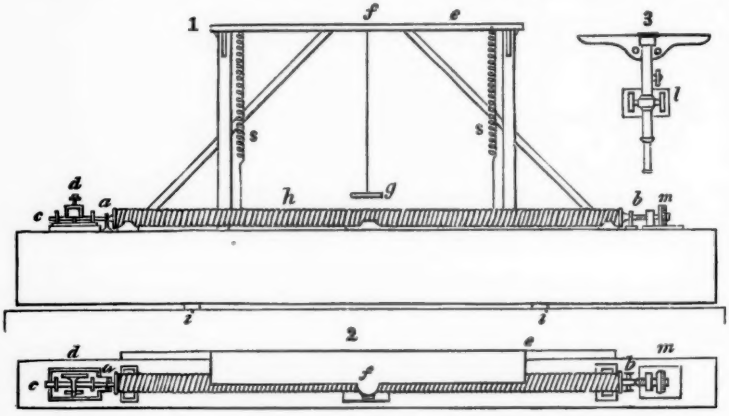
To study and measure with precision the minute elongations and retractions which rods of iron and steel undergo on their magnetization and demagnetization, it is necessary that the motions of the part of the measuring apparatus which records these changes in length should not be in the least affected by outside vibrations transmitted to the apparatus, but should be controled alone by the molecular motions in the rods which take place on changes in their magnetic conditions; also the motions of this indicating part of the apparatus should be synchronous with the motions in the rods, so that we may be able to study the character as well as the amount of these elongations and retractions.

Several instruments have been devised by me which fulfill these essential conditions, but they were all abandoned (except one to be described in detail in Part IV of this memoir), and preference given to "The Reflecting Comparator and Pyrometer" of our esteemed colleague, Mr. Joseph Saxton; this simple and precise instrument is well known to American scientists as

the apparatus which has greatly aided in giving to the geodetic work of our National Coast Survey its renowned precision, and in rendering accurate the comparisons and constructions of our office of Weights and Measures. A detailed description, with drawings, of this instrument will be found in the "Report on the Construction and Distribution of Weights and Measures, Washington, D. C., 1857," written by Dr. A. D. Bache, the late President of the Academy.*

The Measuring Instrument.

I will now describe the actual adaptation of this instrument to our research. The drawings 1 and 2 give respectively an



elevation and plan of the apparatus. A beam of Georgia pine, well seasoned, dried and then soaked with shellac varnish, formed the base on which the instrument was lined and firmly attached. This beam is 7 feet long, $8\frac{1}{4}$ inches deep, and $5\frac{3}{4}$ inches wide. It rested on slips of hard wood at *i*, *i*, placed at distances from the ends of the beam equal to one-fourth of its length. At *a* and *b* are two Vs of brass which supported the terminal brass caps of the rods experimented on. These rods were all 60·1 inches long, ·5 inch in diameter; and each rod weighed, on the average, 1520 grams. While the ends of a rod rested in the Vs, 1100 grams of its weight was supported by the two springs, *s s*, which took hold of the rod at distances from its ends equal to $\frac{1}{4}$ of its length. The flexure of the rod was thus in great part avoided, and it could therefore be accurately centered against its agate terminal. This operation was performed as

* To my friend and colleague, Dr. J. E. Hilgard, of the U. S. Coast Survey office, I am indebted for the loan of the comparator used in these researches.

tered in the helix *h*. This helix is 60·25 inches long, and has an outside diameter of 1·75 inch. It is wrapped on a tube of brass of ·8 inch internal diameter, slit longitudinally throughout its whole length. At *m* is the micrometer abutting-screw, against which the end of the rod is firmly pressed by two heliacal springs, which are stretched between hooks on the brass mountings of the screw and a rod which passed through the terminal brass caps of the rod. The brass caps, at both ends of the rod, are terminated by pieces of agate. The other end of the rod is in contact with a slide *c*, with triangular section which accurately moves, between guides, in a direction which is the axis of the rod prolonged. To this slide is attached a delicate fusee-chain, which is coiled once around the vertical axis of the mirror *d*. This chain is prevented from slipping by a steel pin which securely attaches it to the axis. The slide carrying the chain is firmly pressed against the terminal agate of the rod by means of a heliacal brass spring. Thus the rod is, at one end, firmly pressed against the micrometer screw, while against the other end presses the slide which is connected with the mirror by the intervention of the fusee-chain; which latter is also tightly stretched. The well-joined framework *e* supports the springs *s s*, and also a divided circle *f*, from whose center dropped either a fiber of silk, or a filament of glass, which supported a magnet of very hard steel *g*. From the oscillations of this magnet, or from its deflections by means of the divided circle and glass filament, were determined the intensities of the residual magnetism of the rods. The deflections of the mirror, caused by the elongations or retractions of the rods, were determined by means of the telescope and the scale, represented at *l*. The telescope and scale were placed between 5 and 6 meters from the mirror, and the scale was divided into millimeters. Each unit of the division given in the experiments corresponds to one centimeter of the scale. The above apparatus was placed in a cellar room, without windows and entirely under ground; and the room was always entered by a door, the bottom of which was on a level with the ceiling of the room. During the course of the experiments the range of variation of temperature of this room did not exceed 0·1° C. in twenty-four hours.

Examination of the stability and degree of precision of the apparatus.

A rod was accurately centered in the helix, and the micrometer screw and the slide of the mirror were brought in contact with its ends. After the heat imparted to the rod and apparatus by handling had been dissipated, and the scale-reading had remained constant for an hour, I pushed the mirror-slide away from the rod and then again allowed it to come

expeditiously as was consistent with the careful avoidance of shocks to the apparatus. The thermometers which were placed near various parts of the apparatus were now read, and it was ascertained that they gave the same readings as before the apparatus was touched. The scale was now read in the telescope, and it was ascertained that the cross-threads bisected the same division observed before the slide was moved; thus showing that the mirror returned to the position it had before its rotation. This important fact was repeatedly confirmed with all the rods and at various stages of the research. Indeed, the measures of hundreds of experiments made on the elongations and retractions of rods also confirmed the confidence I obtained in the indications of the apparatus arrived at by the preceding experiments. Jumping on the floor of the room, and the passage of carriages and carts in the streets, had not the slightest effect in disturbing the scale-readings.

To ascertain whether the mirror accurately followed the changes in length of the rod, I repeatedly made the following observation. The readings of the screw-head and the scale were noted; then the screw was rotated by an assistant, so as to push before it the rod. The scale-readings ran up steadily with the rotation, and when the screw was rotated backward the scale-readings ran smoothly down, and when the screw-head had reached the same position it had before it was touched I found that the scale-reading corresponded to that noted when the screw previously had this position. This observation repeatedly made gave me the means of testing the precision of the instrument during the progress of the investigations.

It will be seen below that one division of the scale, or centimeter, corresponded to a change of ·00011 inch in the length of the rod; but $\frac{1}{2}$ millimeter, or $\frac{1}{20}$ of a division, could be precisely read in the telescope; I am therefore justified in believing that the measures I will give in this memoir can be relied on to the $\frac{1}{2000}$ of an inch.

Determination of the value of one division of the scale in changes of length in inch-measure of the rods.

Pasted on the inside of the box in which the mirror, telescope and micrometer-screw came to me, was the following: "Abutting-screw of field-pyrometer. By 7 comparisons of 5 turns with 0·1 inch on Troughton-scale, in June, 1857, by Mr. Saxton, 1 turn=0·01912 inch."

As the result of numerous determinations, made on various parts of the screw, I found that $\frac{1}{100}$ of a rotation of the screw equaled 1·737 divisions of the telescope scale; which gives 0·00011 inch as the value of one division of the scale. This value, however, applies only to the experiments on the rods of

iron, Nos. 1 to 6 inclusive. Before commencing the experiments on the rods of steel, the distance of the scale from the mirror was changed, and in this new position I found that one division of the scale corresponded to 0·000146 of an inch.

Description of the helix and measures of the resistances of its wires.

The helix was a compound one, formed of four layers of copper wire. The two inner layers formed 1069 turns of one length of 303 feet of wire ·087 inch in diameter. The two outer layers were formed of another length of 330 feet of ·112 inch wire wrapped in 850 turns. These two helices could be used separately, or joined into one helix of 633 feet having 1919 turns.

The resistance of the inner helix was ·44 ohm; the outer had a resistance of ·31 ohm; together giving a resistance of ·75 ohm. The latter resistance, added to that of the wires leading from the battery through a Gaugain galvanometer to the helix and back to the battery, brought up the resistance to nearly one ohm.

A battery of 25 cells of Bunsen was used in the determinations of the coefficients of elongation and retraction; and the above interpolar resistance showed that the maximum effect of magnetization would be given by connecting the 25 cells, 5 in couple and 5 in series.

Whenever in this research we speak of the effect of 25 cells, it is to be understood that they are connected as just described.

The iron and steel rods used in the experiments were prepared for me with the well-known skill and fidelity of Mr. William Wallace of Ansonia, Ct. He carefully selected the material, and annealed the iron rods by packing them with iron scales from a rolling mill, in a wrought-iron covered box, and exposing the box to a red heat for three days; the box was then allowed to cool very slowly. The steel rods were tempered as uniformly as possible throughout their lengths.

Arrangement of the Apparatus, and general description of the phenomena which take place on the magnetization and demagnetization of the rods of iron.

The beam supporting the apparatus was so placed that the axis of the helix was in the magnetic meridian. Each rod, before it was introduced into the helix, was tested, as to its magnetic condition, by placing its length at right angles to the magnetic meridian and pointing it toward the center of a magnetic needle. When the rod, thus directed, gave indications of polarity, its S end was placed downward with the axis of the rod in the line of the dip, and its upper end was struck with a light mallet. The rod was tested, until after one or more opera-

tions of this kind it gave no indications of polarity. But on placing the rod in the helix, it of course was again magnetized, but feebly, by the earth's induction. This fact serves to determine the distance at which the magnet, which determined the residual polarity, had to be suspended above the rod. If this magnet is placed too near the rod, an interaction between it and the soft iron of the rod takes place by the inductive action of the magnet, and the vibrations of the latter are more frequent than when it is alone acted on by the earth; but if it be removed to a certain distance above the rod, then the magnetism of the rod acts as a "damper" on the magnet, and its vibrations are slower than when it is only under the earth's influence. There is, therefore, an intermediate position at which the magnet vibrates the same, whether the rod remains under it or is taken away. This distance, of course, varies with the rod used, but on an average it was about 3 inches.

Thus arranged, the rod was allowed to remain until its temperature had become constant, and the scale reading in the telescope was stationary.

The interpolar connections with the battery were made so that the helix, on closing the circuit, would magnetize the rod with the same direction of polarity it already had from the earth's action. The current was now passed from the 25 cells by plunging the amalgamated wire of the open part of the circuit into a cup of mercury; then the scale-reading was immediately noted; the circuit was at once broken, and another reading obtained. The thermometers which were placed on various parts of the apparatus, and which had been read just before closing the circuit, were now again observed, and the room vacated and closed. At intervals of a half hour during the three to six subsequent hours the room was entered, and readings of scale and thermometer obtained.

It may be well to give here a general account of the phenomena which the rods exhibit when the voltaic circuit is successively closed and opened. When the rod has, for the first time, the heliacal current passed around it, a sudden elongation takes place, and this elongation remains steadily of the same amount as long as the circuit is closed and the temperature of the rod remains constant. Now, on breaking the circuit, the rod retracts, with a less velocity than that with which it elongated, but the retraction does not equal the elongation.

The temperature of the rod remaining constant, it has been found that the rod retains the length it attained on the breaking of the circuit; that is, the rod has received, with its permanent magnetic charge, a permanent elongation. On passing the current a second time the rod again elongates, but the elongation is now less than that which took place when the current

was first passed around it. On now breaking the circuit the rod retracts to the length it had before the current was passed for the second time. That is, after the first magnetization and demagnetization of the rod, the successive elongations and retractions are equal. These conditions exist until four or five subsequent make and break-circuits have been made; but now a change takes place in the phenomena, for on making the circuit the rod elongates about the same as in the preceding experiments, *but on breaking the circuit* the retraction does not equal the elongation; so that after each experiment the rod is slightly longer than before the preceding experiment was made. Continuing the experiments, the scale gradually passes over the cross-threads, and I have thus repeatedly caused the entire scale to traverse the field of the telescope. On now allowing the rod to remain at the temperature it had when the current was for the first time passed around it, the rod slowly retracts until, after several hours have elapsed, the rod has the length which was observed after the first experiment made upon it.

Heat developed in the rod at the instant of its demagnetization.

The above described experiments show conclusively that the minute elongations which take place on breaking the circuit are due to the heat developed in the rod at the moment of its demagnetization; for, in the preceding experiment the current did not heat the helix sufficiently to cause radiations from it to elongate the rod; therefore, to obtain the results described above, it is important to ascertain beforehand that when the current has traversed the helix for a time equal to that occupied in the experiments, the rod during this time does not elongate.

If the current is sufficiently intense to heat directly the helix and rod, the above phenomena of heating on demagnetization nevertheless manifests itself and can readily be disentangled from the combined effects, as will be seen further on.

These interesting results proving the development of heat on demagnetization, were obtained a year ago without any knowledge of the recent work of Jamin and Roger, and the measures made directly on the changes in length of the rods, tend to confirm the result arrived at by these experimenters.* Recently Cazin (Compt. Rendus, t. lxxv, p. 1265), has shown that "the heat thus produced is proportional to the square of the intensity of the magnetism and to the polar distance:" and Moutier,

* I have not been able to find the paper containing Jamin and Roger's experiments, either in the Comptes Rendus or in the Ann. de Ch. et de Phys. I have obtained the information of their results only from the following passage in the paper of M. Cazin, C. R., t. lxxv, p. 1266. "When we pass an intermittent current in the wire of an electro-magnet, the recent experiments of MM. Jamin and Roger have demonstrated in a definite manner that the core is heated." The method by which they discovered this fact is not stated by Cazin.

(Comptes Rendus, t. lxxv, p. 1620), deduces this result from a thermodynamic theorem established by Clausius, and thus concludes his paper: "The increase of *vis viva* which the bar experiences from the effect of magnetization is therefore proportional to the square of the intensity of the magnetism and to the polar distance. The effects of the demagnetization correspond to an equal loss of *vis viva*, which is the measure of the thermal effect produced, and this effect is the only one which accompanies the demagnetization."

The fact that an iron bar is heated by successive magnetizations and demagnetizations has been known for a long time, but only recently have experiments been made which indicate that this heat is produced at the moment of demagnetization. In a paper "On the Calorific Effects of Magneto-Electricity, and on the Mechanical Value of Heat," (L. E. and D. Phil. Mag., vol. 23, 1843), Dr. Joule first showed that heat was developed in an iron bar when it was rotated between the poles of a powerful magnet, and also determined that the heat thus produced was proportional to the square of the inductive force. These experiments will ever be regarded with interest, for they led Joule to the first experimental determination ever made of "the mechanical value of heat."

It may be of interest to present the following account of the experiments made by Van Breda and Grove, taken from Daguin's Traité de Physique, 1861, vol. III, p. 621. "M. Van Breda having enveloped a tube of iron with a helix through which he passed an intermittent current, found a heating of the iron due to the alternative displacement of the molecules,* the heat being shown by the dilatation of the air contained in the tube, which formed a reservoir of an air thermometer. Grove subsequently determined the heating of an armature of soft iron, on passing an intermittent current in the wire of an electro-magnet on which the armature was placed, or in turning near it the poles of a strong electro-magnet. The heating effects were indicated by a thermo-electrical couple. Cobalt and nickel gave similar results, but less marked; while non-magnetic metals were not heated in the same circumstances. I have made many experiments on a tube of iron, weighing two hundred weight, which confirm these results. The experiments will be given in Part III. of this memoir.

I here present two tables of experiments on rod No. 2, of Ulster iron. The successive discussion of these two tables will give to the reader a clear physical conception of the phenomena, and serve to elucidate the account I have above given of the heat developed on demagnetization.

* The heat observed, however, may not be entirely due to these motions, for the thermal effects may in part be due to the currents induced in the iron on magnetization and demagnetization.

TABLE I.

No. of Expt.	Scale, circuit open.	Scale, on closing circuit.	Scale, on breaking circuit.	Elongation.	Retraction.
1	37·6	39·2	38·0	1·6	1·2
2	38·0	39·2	38·0	1·2	1·2
3	38·0	39·2	38·0	1·2	1·2
4	38·0	39·2	38·0	1·2	1·2
5	38·0	39·2	38·0	1·2	1·2
6	38·0	39·2	38·1	1·2	1·1
7	38·1	39·3	38·1	1·2	1·2
8	38·2	39·4	38·3	1·2	1·1
9	38·3	39·5	38·4	1·2	1·1
10	38·4	39·55	38·6	1·15	0·95
11	38·6	39·6	38·6	1·0	1·0
12	38·6	40·0	38·85	1·4	1·15
13	38·85	40·1	39·0	1·25	1·1
14	39·0	40·2	39·1	1·2	1·1
15	39·1	40·2	39·2	1·1	1·0
16	39·2	40·3	39·2	1·1	1·1
17	39·2	40·4	39·3	1·2	1·1

In experiment No. 1, we passed the current for the first time around the unmagnetized rod, and observed an elongation of 1·6 divisions of the telescope-scale. Immediately after the observation we broke the circuit, which had remained closed about 5 seconds, and observed a retraction of 1·2 div.; the rod now remained at a constant temperature for three hours and the scale-reading remained steady at 38·0; thus showing that the rod had received a permanent elongation of ·4 of a division on receiving its charge of residual magnetism. On repeating the experiment, we find an elongation and retraction of 1·2 div., which is the quantity the rod retracted on the first break-circuit. Experiments 2 to 5 inclusive give the same result; but on the 6th and subsequent break-circuits, we observe a retraction less than 1·2, and this effect we attribute to the heat produced in the rod at the instant of its demagnetization. It is also noteworthy, that from the moment of breaking the circuit in an experiment until the forming of it in the succeeding one, the scale remained immovable. Taking 1·2 div. as the amount of elongation and retraction due alone to magnetization and demagnetization, we can determine the mean amount of elongation at the moment of demagnetization as follows: The mean elongation in experiments 6–17 is 1·18 div. This is only ·02 of a div. less than 1·2, and can candidly be attributed to the errors of observation, but the mean retraction of the same experiments is 1·08 div., which is ·12 of a division less than 1·2, and gives us the measure of the effect due to the heating of the rod at the moment of its demagnetization; for, on keeping the rod at the temperature it had during experiments 1–5, we found that it gradually retracted until the scale again remained steady at 38·0.

Table II is here given to show that nearly the same effects of elongation and retraction are observed when the rod is

gradually elongating under the effects of heat radiated from the helix, when the latter has passed through it a powerful current.

TABLE II.

No. of Expt.	Scale, circuit open.	Scale, on closing circuit.	Scale, on breaking circuit.	Elongation.	Retraction.
18	51·4	52·8	51·8	1·4	1·0
19	51·8	53·2	52·2	1·4	1·1
20	52·2	53·4	52·4	1·2	1·1
21	52·5	53·8	52·7	1·3	1·1
22	52·8	54·0	52·9	1·2	1·1
23	53·0	54·3	53·2	1·3	1·1
24	53·2	54·5	53·5	1·3	1·0
25	53·5	54·7	53·6	1·2	1·1
26	53·8	55 2	54·2	1·4	1·0
27	54·2	55·4	54·4	1·2	1·0
28	54·4	55·6	54·5	1·2	1·1
29	54·5	55·7	54·7	1·2	1·0
30	54·8	55·8	54·75	1·0	1·05
31	54·8	56·0	55·0	1·2	1·0
32	55·0	56·2	55·2	1·2	1·0
33	55·2	56·3	55·25	1·1	1·05
34	55·25	56·4	55·4	1·15	1·0
35	55·4	56·45	55·5	1·05	0·95

The experiments in this table were made on the same rod used in the experiments in Table I, but before this new series was commenced I passed around the helix a stronger current than previously used, so that the rod was elongated, by the heated helix, from 39·2 divisions of the scale to 51·4 divisions, and while the scale was advancing to this reading I determined its rate of progress and found it to be 3·6 divisions in 10 minutes. Therefore these experiments were made on the rod while it had a slow motion of elongation. The mean of the elongations is 1·22 divisions. The mean of the retraction is 1·04 div., which subtracted from 1·20 gives ·16 of a division for the effect of the heat of one demagnetization. The reduction of Table I gave ·12 of a division for this effect. The difference in the two results I thus account for. While the bar was slowly expanding from the heat radiated from the helix, the circuit was made and the elongation was immediately observed, but about five seconds elapsed before the reading could be made, and the circuit broken, and during these five seconds the rod was expanding, but so slowly that its amount could not be read, but was often visible. That this minute expansion could not be determined was to be expected, for if the rod elongated from heat 3·6 divisions in 10 minutes, it elongated only ·03 of a division in five seconds, and ·03 of a division was a quantity too small to be measured on the scale, but it nevertheless existed there, and during the continuance of 18 make-circuits would amount to $·03 \times 18 = ·54$ of a division; quite an appreciable quantity when we come to calculate the mean with this frac-

tion contained in the sum of retractions given in the last column of the table. Therefore, to obtain the effect of the heat developed at the moment of demagnetization, we should subtract ·03 from ·16, the heating effect of demagnetization determined without this correction. This gives ·16−·03=·13 of a division; while from Table I we deduced ·12 for the value of the same effect. The difference of only ·01 division in the two results is not, however, to be taken without some reserve, for in the calculations I assumed that the rod had the same rate of expansion under a closed circuit as under an intermittent one, and this I did because I had no means of determining the difference, if any exist. Experiments similar to those just given were made on all the iron rods, and similar results were obtained.

Relations existing between the number of break-circuits, the heating of the rod, and its elongations.

At this stage of the investigation, it became of interest to determine the above relation. For that purpose I drilled a hole six inches deep in the direction of the axis of rod number 3, of Norway iron, and inserted into this hole a thermo-electric couple, formed of two wires, one of copper, the other of iron. This compound wire was wrapped, first with two layers of waxed silk, then with twelve layers of floss-silk, and over these layers I coiled two more layers of waxed floss-silk, leaving, however, the point of junction of the wires exposed.

This apparatus was introduced into the rod so that the uncovered point of the wire was about one millimeter from the bottom of the hole, and the space included between the point of the wire and the bottom of the hole was filled, in some experiments with fine iron filings, in others with mercury. The terminals of the thermo-electric couple were connected with a delicate galvanometer. With the apparatus thus arranged, I successively made 50, 100, 200, 300, and 400 break-circuits, taking care that the closed circuits, preceding the break-circuits, should all be of the same duration.

After each series of break-circuits the elongation produced in the rod and the permanent deflection in the galvanometer-needles were noted, and the observations showed that the elongations and the increments of temperature in the rod were proportional to the number of break-circuits.

On the elongations and retractions observed in the iron rods as the strength of the magnetizing current is gradually increased and diminished, and on the equality in the elongations produced by a definite current when it is gradually and when it is suddenly brought up to its maximum strength.

The observed sudden elongations taking place in an iron rod at the moment of its magnetization naturally led me to inquire

if the quantity of this elongation was in any way due to the suddenness of the magnetizing action, and whether the elongation produced by a certain current which is gradually brought up to its maximum strength would equal that produced by the same current suddenly passed with the same maximum strength. This problem was also connected with a proposed simple and accurate means of measuring the changes in dimensions of bodies subjected to magnetization, and I have therefore examined it with care in the following manner. I cut the thick copper wire leading from the battery to the helix and firmly attached one of its loose ends to a support. Between this copper wire and the opposite wall I stretched a fine wire of german-silver. The other loose end of the battery wire was bent into a sharp angle and the vertex of this angle was well amalgamated. Now by sliding this bent copper wire along the fine wire of german-silver toward the other copper wire, I could gradually diminish the resistance, and on touching the other end of the thick battery wire, this interposed resistance vanished and the current gained its maximum strength. On slowly retracing our steps the resistance was gradually increased, until the whole length of the fine wire was interposed, and then the resistance was at its maximum and the strength of the current was at its minimum. But if we brought the two amalgamated ends of the copper wire in contact, either with or without the intervention of a mercury cup, we at once could suddenly send the current with its maximum intensity through the helix.

Mean results of 1*st series of experiments. Resistance of fine wire* = ·6 *ohm.* One cell in circuit.

On gradually diminishing the resistance.

Fraction of length of fine interposed wire.

		1	⅘	⅗	⅖	⅕	0
Scale-readings went from	54·8 to	54·85	54·9	55	55·2	55·6	56·1

On gradually increasing the resistance.

Scale-readings went from	55·5 to	54·8	55·6	55·8	55·9	55·95	56·1
Tangent galvanometer,		4¾°	---	---	---	-- -	29½°

Mean results of 2*d series of experiments. Resistance of fine wire* = ·9 *ohm.* One cell in circuit.

On gradually diminishing the resistance.

Scale-readings,		54·8	54·8	54·85	55	55·4	56·1

On gradually increasing the resistance.

Scale-readings went from	55·25 to	54·8	55·4	55·65	55·8	55·9	56·1
Tangent galvanometer,			3°	----	---	---	29½°

Examining the results in the two series of experiments, we see that where the current was passed, with all of the interposed resistance in the circuit, the scale went from 54·8 to 54·85, or moved ·05 of a division in the first series of experiments; but in the second series the current was too feeble to effect a measureable elongation, and it was not until $\frac{1}{4}$ of the fine wire was out of the circuit that the scale-reading began to increase. In both series of experiments the rapid increase in the rate of elongation is noticeable after $\frac{3}{4}$ of the fine wire was out of the circuit; the elongation, in both series of experiments, amounted to 1·3 divisions of the scale. The same amount of elongation always occurred when the ends of the copper wires were brought together, or when the circuit was as suddenly formed by plunging the wires into a cup containing mercury. Therefore, it is well established that a current of a definite strength will produce the same amount of elongation whether that strength is suddenly or gradually attained. Indeed, in some of the experiments over three minutes were occupied in gradually decreasing the interposed resistance, until it was entirely out of the circuit, yet during this very slow increase of the current strength, the scale slowly and smoothly moved upward in its readings, and when all the interposed resistance had been passed over the elongation again equaled 1·3 division.

The establishment of the above fact was of considerable importance, for it rendered applicable the following simple and precise method of measuring the change in dimensions of bodies on their magnetization. Two iron, steel or bismuth bars are placed parallel to each other, in Vs, with their similar ends strongly pressed against a firm support, so that if the rods change their length on magnetization, their free ends will move.

Now imagine a lever so arranged that one end of it carries a plano-convex lens and the other end a micrometer screw. The convex side of the lens is opposite a plane glass, which terminates the end of one of the rods, while the point of the micrometer screw touches the end of the other rod, against which it is pressed by a spring. An inclined piece of plane glass placed in front of the lens, sends the light from a sodium flame down to the lens and plane glass behind it, and by means of a microscope we can look through the inclined glass on to the lens and thus accurately view and measure the Newton's rings, which we will now observe. If around the rods we now pass a voltaic current of gradually increasing strength, we will see the rings gradually displaced, and from the amount and direction of this displacement, together with the knowledge of the wave-lengths of the rays of the sodium light, we can accurately determine the amount and direction of the motion of the ends of the rods.

If, however, the current should have been passed at once with its full intensity, there would have followed a sudden dis-

placement of the rings, but the amount and direction of this displacement it would have been impossible to determine. By making the arm of the lever which carries the convex lens longer than the arm which carries the screw, we can increase the delicacy of the apparatus, for it is understood that, as the rods move in the same direction, the rod carrying the plane glass moves toward the lens, while at the same time the other rod, through the intervention of the lever, pushes the lens toward the plane glass.

The examination of the experiments of the first and second series contained under the heading, "On gradually increasing the resistance," makes known a remarkable phenomenon. In these experiments the current, with its maximum strength, was first passed through the helix and then it was gradually brought down to its minimum strength by sliding the copper battery wire over the fine wire of german-silver until the whole length of the latter was brought into the circuit. At the moment of sending the current with its maximum strength, the rod elongated 1·3 divisions of the scale; but if we now keep the circuit closed, but gradually diminish the strength of the current, we observe that the scale-readings do not correspond to those given when the corresponding strengths of current were reached by going from their mimimum to their maximum, as the following tables, giving the differences of scale-readings in the two cases, plainly show.

First series of experiments.

Fraction of length of fine interpolar wire,	1	¾	½	¼	⅛	0
On gradually diminishing the current,	55·5	55·6	55·8	55·9	55·95	56·1
" " increasing the current,	54·85	54·9	55·0	55·2	55·6	56·1
Differences,	·65	·7	·8	·7	·35	·0

Second series of experiments.

Fraction of length of interpolar wire,	1	¾	½	¼	⅛	0
On gradually diminishing the current,	55·25	55·4	55·65	55·8	55·9	56·1
On gradually increasing the current,	54·8	54·8	54·85	55·0	55·4	56·1
Differences,	·45	·6	·8	·8	·5	·0

We thus see that the rod tends to persist in the elongation it acquired in first passing the maximum current, for it does not retract in proportion to the diminished strength of this current; and the experiments show that even when the current is so far diminished in strength that it would, if suddenly thrown through the helix, be unable to elongate the rod sufficiently to be measurable, yet this feeble current holds the rod elongated ·45 of a division in the second series of experiments, but on breaking the circuit the rod instantly retracts ·45 of a division in the second series of experiments and ·65 of a division in the

first series, and regains the length it had before the current was passed around it.

On passing the current with the whole of the fine wire in the circuit, we have, in the first series of experiments, an elongation of ·05 of a division, but on making the circuit without the interposed fine wire, we have an elongation of 1·3 divisions; and if we now do not break the current, but gradually diminish its strength by increasing the interpolar resistance, we find that when the whole of the fine wire is again in the circuit that the elongation is yet ·65 of a division: whereas when the circuit was at once formed with this same interposed resistance the rod was elongated only ·05 of a division.

The discovery of this most remarkable phenomenon was contained in the above experiments, but to be sure that my experiments should not mislead me, I repeated them several times, using every precaution to ensure their accuracy, and obtained results almost identical with those formerly observed. I am therefore confident that I have discovered a phenomenon worthy of minute study, and I purpose to make it the subject of a special investigation.

Unfortunately, during the above experiments, I did not make a parallel series of determinations of the magnetic intensities of the rod during the successive stages of passing a current of increasing and of decreasing strength. Yet I can hardly believe that the magnetic intensity will be kept up with the persistent elongation of the rod when it is slowly demagnetized, but I think that it will be found that the magnetic intensity of the rod depends alone on the strength of the current traversing the helix. The phenomenon indeed shows that the molecules of the rod, on its elongation by magnetization, having been forced into new positions, that either by what might be well called a "*magnetic set*"* or from molecular friction, the molecules retained these new positions with such persistence, that it required the sudden shock of the induced current, produced on breaking the circuit, to cause them to rush to their positions of stable equilibrium.

Effects observed on making and breaking separate currents in the component helices of the compound helix.

In these experiments two batteries were used. In the outer helix I made and broke a current from 16 cells, arranged four coupled and four in series. In connection with the inner helix, I used a battery of 25 cells, connected five in a row and five in series. The experiments are interesting as showing the effects

* The term "magnetic set," as appplied above, is from analogy an appropriate name for the phenomenon; but it cannot well be so applied, for Dr. Joule has already appropriated "magnetic set" as designating the residual magnetism an iron rod retains after its electro-magnetization.

of the induced currents formed on making and breaking the circuits in the various manners given in the following experiments.

(1.) Made circuit in inner helix, rod elongated 1·4 division.
" " " outer " " " ·25 "
Broke " " " " " retracted ·25 "
" " " inner " " " 1·4 "

(2.) Made circuit in outer helix, rod elongated 1·5 divisions.
" " " inner " rod suddenly retracted ·4 div., and then suddenly elongated ·4 division.
Broke circuit in inner helix, rod suddenly retracted ·4 div., and then suddenly elongated ·4 division.
Broke circuit in outer helix, rod retracted 1·5 divisions.

(3.) Made circuit in inner helix, rod elongated 1·4 divisions.
" " " outer " " " ·25 "
Broke circuit in inner helix, rod suddenly retracted ·35 division, then suddenly elongated ·35 division.
Broke circuit in outer helix, rod retracted 1·65 divisions.

(4) Made circuit in outer helix, rod elongated 1·5 divisions.
Made circuit in inner helix, rod suddenly retracted ·5 division, then suddenly elongated ·05 division.
Broke circuit in outer helix, rod retracted ·1 division.
" " " inner " " " 1·4 divisions.

On the times occupied in the elongations and retractions of a rod when the two component helices are joined as one helix, and placed in the circuit of one battery.

The determinations I here give were made with the eye and a chronograph, and although not as accurate as the interest of the research demands, yet are near enough to the truth to show that the subject is worthy of a careful investigation. The experiments given under the above heading and the succeeding one, give an insight into the *velocities* of the molecular motions, and therefore these determinations, taken in connection with the measures of the corresponding elongations and retractions, will be of considerable theoretic interest, when they have been determined with the precision which the following proposed apparatus will, in all probability, afford.

I thus propose to attack this problem. The mirror of the apparatus will be made of the minimum weight consistent with stability. The mirror will reflect a pencil of light from an electric lamp to a revolving glass disc coated with sensitized collodion. This converging pencil will form a dot of light on the disc and when the latter is stationary will, on the elongation of the rod, describe a portion of one of its radii, which will appear on developing the sensitized plate. If, however, the disc have

an uniform and known rate of rotation, the dot will on the elongation of the rod, describe a curved line which, referred to the appropriate ordinates, will give not only the time of the motion of elongation, but also the mode or law of this motion. Of course the motion of retraction can be studied in like manner.

The following experiments were made on rod No.3, of English refined iron, and each result is the mean of 50 experiments.

	Time of elongation.	Time of retraction.
(1.) 25 cells,	$\frac{1}{2\,1\,0}$th of a second.	$\frac{2}{1\,0}$ths of a second.
(2.) one cell,	$\frac{3}{1\,0}$ths " "	$\frac{1}{1\,0}$th " "

It is thus seen that, with 25 cells, the duration of the retraction is six times as long as the duration of the elongation, but with a current from one cell the phenomena are reversed and the duration of the elongation is three times that of the retraction.

Determinations of the times occupied in the elongation and the retraction of a rod when the inner or the outer helix forms in itself a closed conductor, while the current is passed, in the respective cases, in the outer and in the inner helix.

(1.) Terminals of inner helix *not* joined. Current passed through the outer helix from 25 cells. Elongation of the rod 1·5 divisions. Times of elongation $\frac{1}{1\,2\,5}$th of a second. Times of retraction, $\frac{1}{4}$ sec.

(2.) Same result as above when the outer helix was open, and the current was passed through the inner helix.

(3.) The terminals of inner helix united; so that this helix formed a closed circuit in itself. Current from 25 cells passed through outer helix. Elongation, 1·5 divisions. Time of elongation, $\frac{2}{1\,0}$ths of a second. Time of retraction, $1\frac{1}{1\,0}$th seconds.

(4.) Same results as above when the terminals of the outer helix were united, and the current passed through the inner helix.

(5.) One cell used. When the terminals of the outer or inner helix were *not* united and the current passed respectively through the inner and outer helix, the elongation was 1·1 divisions. The time of elongation, $\frac{3}{1\,0}$ths of a second. The time of retraction $\frac{2}{1\,0}$ths of a second.

(6.) One cell used. The terminals of inner helix united. The elongation was 1·1 divisions. Time of elongation, $\frac{6}{1\,0}$ths of a second. Time of retraction $1\frac{3}{1\,0}$ths seconds.

(7.) Same result as experiment (6) when the terminals of outer helix were joined, and the current from one cell passed through the inner helix.

To observe a rod slowly retracting during 1·3 of a second was a most remarkable sight, and suggests many thoughts as to the interaction of the induced currents passing in the helices and

rod. I may here venture to suggest that the study of these extraordinary phenomena—which I believe I have here first made known—will eventually be of some service in the study of induced currents. For the present, I am content with merely presenting *the facts*, for I have not yet been able to command the time which their investigation will require.

In experiments (3) and (6) the time of retraction was respectively $1\frac{1}{10}$ seconds and $1\frac{3}{10}$ seconds, and the slowness of these motions allowed me to obtain an insight into their character. In each of these experiments the rod retracted with a gradually diminishing velocity, and the motion reminded one forcibly of that pertaining to a body projected vertically upward.

The coefficients of elongation and of retraction of seven rods of different species of iron, and of three steel rods of various degrees of hardness.

It remains to give the determinations I have made of the coefficients of elongation and of retraction. Those measures were made on rods of circular sections, 60·1 inches long and ·5 inch in diameter. As previously stated, the iron rods were thoroughly annealed, and the steel rods were carefully tempered. On the ends of the rods, numbers were stamped, and these marks corresponded to the rods as follows:

1. ——— Scrap Iron.
2. ——— Ulster Iron.
3. ——— Norway Iron.
4. ——— English refined Iron.
5. ——— Low Moor Iron.
6. ——— Fall River Iron.

000. ——— Steel soft.
00. ——— Steel hardened and drawn to blue.
0. ——— Steel hardened and drawn to yellow.

The method of determining the coefficients was as follows: When the rod had attained a fixed temperature, so that the scale-reading remained constant for an hour, I recorded this scale-reading. I then passed the current from the 25-cell battery, and so soon as the new scale-reading then produced was read, I broke the circuit and obtained the corresponding scale-reading. These readings were now written in the note book, and immediately after recording them, I again made and broke the circuit and noted the two corresponding readings of the telescope-scale. I then continued making and breaking the circuit and recording the scale-divisions, until the rod began to elongate from the heat produced on demagnetization.

The tables I here present consist of six columns, A, B, C, D, E, and F. Under A are designated the rods; B contains the elongations or retractions produced on first passing the current;

C the retractions or elongations observed after the first made circuit had been broken; D the permanent elongations or retractions observed in the rod after the first circuit passed had been broken; E the elongations or retractions produced on making the second and subsequent circuits; F the elongations or retractions produced on breaking the second and subsequently formed circuits.

Table of the Elongations and Retractions of the Rods.

TABLE I.

Elongations and Retractions in Units of the Telescope-scale.

A. Rod.	B. 1st make-circuit.	C. 1st break-circ'lt.	D. Permanent *e* or *r*	E. 2d make-circuit.	F. 2d break-circuit.
1	1·25 *e*†	·75 *r*	·4 *e*†	·7 *e*†	·7 *r*†
2	1·6 *e*	1·2 *r**	·4 *e*†	1·2 *e*	1·2 *r*
3	2·0 *e*	·9 *r*	1·1 *e*	1·4 *e**	1·4 *r**
4	2·5 *e**	1·15 *r*	1·35 *e**	1·15 *e*	1·15 *r*
5	1·65 *e*	·6 *r*†	1·05 *e*	1·0 *e*	1·0 *r*
6	1·4 *e*	·85 *r*	·55 *e*	·9 *e*	·9 *r*
000	·8 *e**	·6 *e**	1·4 *e**	·25 *r*	·25 *e*
00	·25 *r*	·5 *e*	·25 *e*	·5 *r**	·5 *e**
0	·4 *r*†	·25 *e*†	·15 *r*†	·2 *r*†	·2 *e*†

TABLE II.

Elongations and Retractions in Fractions of an inch.

A.	B.	C.	D.	E.	F.
1	·0001375 *inch*	·0000825 *inch*	·000044 *inch*	·000077 *inch*	·000077 *inch*
2	·000176 "	·000132 "	·000044 "	·000132 "	·000132 "
3	·000220 "	·000099 "	·000121 "	·000154 "	·000154 "
4	·000275 "	·0001265 "	·0001485 "	·0001265 "	·0001265 "
5	·0001815 "	·000066 "	·0001155 "	·000110 "	·000110 "
6	·000154 "	·0000935 "	·0000605 "	·000099 "	·000099 "
000	·0001168 "	·0000876 "	·0002044 "	·0000365 "	·0000365 "
00	·0000365 "	·0000730 "	·0000365 "	·0000730 "	·0000730 "
0	·0000584 "	·0000365 "	·0000219 "	·0000292 "	·0000292 "

TABLE III.

Coefficients of Elongations and of Retractions.

A.	B.	C.	D.	E.	F.
1	·000002288 *e*†	·000001377 *r*	·000000732 *e*†	·000001281 *e*†	·000001281 *r*†
2	·000002928 *e*	·000002196 *r**	·000000732 *e*†	·000002196 *e*	·000002196 *r*
3	·000003660 *e*	·000001647 *r*	·000002013 *e*	·000002562 *e**	·000002562 *r**
4	·000004575 *e**	·000002105 *r*	·000002471 *e**	·000002088 *e*	·000002088 *r*
5	·000003019 *e*	·000001098 *r*†	·000001921 *e*	·000001830 *e*	·000001830 *r*
6	·000002562 *e*	·000001555 *r*	·000001006 *e*	·000001647 *e*	·000001647 *r*
000	·000001943 *e**	·000001457 *e**	·000003400 *e**	·000000607 *r*	·000000607 *e*
00	·000000607 *r*	·000001212 *e*	·000000607 *e*	·000001212 *r**	·000001212 *e**
0	·000000972 *r*†	·000000607 *e*†	·000000364 *r*†	·000000486 *r*†	·000000486 *e*†

* Maximum. † Minimum.

After the quantities given in the columns, I have written *e* to designate the *elongation* of the rod, and *r* to indicate its *retraction*.

I have given the measures in three tables. Table I contains the elongations and retractions in the actual scale units. It is here to be remembered that one division of the scale equals 0·00011 of an inch for the experiments on rods No. 1 to No. 6 inclusive; while for the remaining rods 000, 00, and 0, one division of the scale equals 0·000146 of an inch. Table II gives the elongations and retractions of Table I expressed in fractions of the inch of "Troughton's scale."*

Table III contains the coefficients calculated from the numbers given in Table II.

Certain numbers of the tables are followed by * or by †; * indicates the maximum effect observed in the iron, or in the steel rods, corresponding to the phase of experiment given in the heading of the columns of Table I, or as subsequently designated by A, B, C, D, etc. An examination of the tables shows that the maxima and minima effects, in the case of the iron rods, are very irregularly distributed. Thus, corresponding to the "first make-circuit," we find that rod No. 4 gives the maximum, while rod No. 1 the minimum. On the "first break-circuit," rod No. 2 is the maximum, while rod No. 5 is the minimum. For the "permanent elongation," rod No. 4 is the maximum, and rods No. 1 and 2 are the minima. In the two columns corresponding to "second make-circuit" and "second break-circuit," we see that rod No. 3 gives the maximum effect observed, while rod No. 1 gives the minimum.

The phenomena of Elongation and Retraction observed in Rods of Steel.

The phenomena observed in the magnetization and demagnetization of the rods of steel have not been referred to. Here we have presented to us remarkable results. On first passing the current around rod 000, of soft steel, it elongated ·8 of a scale-division, behaving like a rod of soft iron; but, on breaking the circuit, to my astonishment, it again *elongated* ·6 of a division, thus leaving this rod with a permanent elongation of 1·4 divisions; and this elongation exceeds the permanent

* "Two copies of the new British Standard, viz., a bronze standard, No. 11, and a malleable iron standard, No. 57, have been presented by the British government to the United States. A series of careful comparisons,—made in 1856, by Mr. Saxton, under the direction of Dr. Bache,—of the British bronze standard No. 11, with the Troughton scale of 82 inches, showed that *the British bronze standard yard is shorter than the American yard by* 0·00087 *inch.* So that in very exact measures with the yard-unit, it is necessary to state whether the standard is of England or of the English feet."

"Lecture Notes on Physics," by A. M. Mayer, p. 12. Van Nostrand, New York. 1868."

elongation given to any of the soft iron rods when similarly experimented on. On passing the current around the rod, *for the second time*, the soft steel rod again did not act like a rod of iron, for it *retracted* ·25 of a division instead of *elongating*, as did the rods of iron in like circumstances; and on breaking this circuit the rod *elongated* ·25 of a division, instead of retracting; again exhibiting a phenomenon the reverse of those observed in the rods of iron; and it is here important to remark, that *all* of the steel rods behaved in the same manner on the making and breaking of the second and subsequently formed circuits.

The results just described differ from those obtained by Dr. Joule. Referring to his memoir (Phil. Mag., vol. xxx, p. 85), we find that experiments on a rod of soft steel, one yard long and a quarter of an inch in diameter, showed that the rod elongated on first passing the current; but on breaking this circuit, the rod *retracted*, while in my experiments, the rod again *elongated* on breaking this circuit. Indeed, the experiments of Dr. Joule indicate that a rod of soft steel behaves like one of iron, except that the elongations and retractions are of less extent than in the case of an iron rod. It is important, however, to observe that Dr. Joule did not, in his first experiment on this rod, pass around it a current sufficient to "saturate" it, but gradually increased the intensity of the current in successive experiments; and it is to be remarked, that as the intensity of the current increased, the retractions and elongations came nearer and nearer to equality, but in no instance did he observe a *retraction* on passing a current and an *elongation* on its cessation.

In his subsequent experiments, Dr. Joule worked on a steel rod of the same dimensions as that used in his former experiment, but it was "hardened to a certain extent throughout its whole length, but not to such a degree as entirely to resist the action of the file." On *first* passing the current, and also in subsequently passing the current with successively increased intensities, he obtained results similar to those I observed in the rod of soft steel, but with this rod also he never observed a *retraction* on making a circuit, and an *elongation* on breaking it. The fact that so eminent an investigator as Dr. Joule obtained, on *first* passing a current around a bar of soft steel, results similar to those obtained by me with my bar of soft steel, leads me to suspect that the rod I experimented on may have retained some degree of "hardness" after it had been annealed; but even this fact granted, does not explain why *all* the steel rods I experimented on gave *retractions* on passing the current a *second* time after they had been "saturated" during the *first* passage of the current.

Examining the results of my experiments on rod 00, of hard steel "drawn to blue," we see that the phenomena are exactly the reverse of those occurring in rods of iron in the same circumstances, except in this one particular, viz., that after breaking the first made circuit the rod is permanently *elongated;* and this result agrees with all of those obtained by Dr. Joule.

The experiments on rod 0, of hard steel "drawn to yellow" are noteworthy. On making the *first* circuit, this rod *retracted* ·4 of a division, and on breaking this circuit, the rod elongated, but only ·25 of a scale division, thus leaving the rod permanently *retracted* ·15 of a division; so that this rod of hard steel, which after the experiment remained a powerful magnet, is *shorter* than it was before it was magnetized. On passing the second current around this rod, it, like the two preceding rods, *retracted* ·2 of a division, and on breaking this circuit, it elongated by the same quantity, so that after the second and subsequent passages of the voltaic current, it persisted in the retraction it received after the first made circuit was broken.

The experiments I have just given on rod 0, differ in every particular from any obtained by Dr. Joule, on rods which were *not subjected to tractile strain.* I cannot but regret that this eminent physicist did not experiment on rods of very hard steel freed, as far as possible, from all strains; for then my experiments would have been strictly comparable with his. The experiments which Dr. Joule made on rods of hard steel (except those I have already quoted) were conducted on rods subject to tractions going from 80 lbs. up to 1,030 lbs., while my experiments were made on rods so supported by brass springs, that only a fraction of their weight was supported by the Vs on which their ends rested.

Referring to Dr. Joule's experiments on a "soft steel wire, one foot long, a quarter of an inch in diameter, tension 80 lbs," we find that this rod behaved like one of soft iron, free of strain, with currents deflecting his galvanometer 34° 40′ up to 56° 30′; but with currents below 34° 40′ no action whatever was observed to take place in the rod, except its magnetization; but when the same rod was subjected to a tension of 462 lbs., and a current of 60° 15′, it behaved like my horizontally suspended steel rod 00; that is, it retracted on making the circuit, but it elongated more than it had previously retracted when this circuit was broken. With a tension of 1,680 lbs. the rod retracted and elongated by equal amounts on making and breaking the circuits. In Dr. Joule's experiments on a "hardened steel wire" one foot long, a quarter of an inch in diameter, tension 80 lbs., he observed no effect until the current reached an intensity of 45° 40′; then this rod also elongated and retracted by equal quantities on making and breaking the circuits. With a ten-

sion of 408 lbs. and of 1030 lbs., this rod behaved in the same manner, but the elongations and retractions did not begin to show themselves with the respective tensions until the currents had respectively reached the intensities of 60° 20′ and 48° 33′. Summing up these results, Dr. Joule states: "From the above experiments, we find that the induction of permanent magnetism produces no sensible effect on the length of a bar of perfectly hardened steel, and that the temporary shortening effect of the coil is proportional to the magnetism multiplied by the current traversing the coil. The shortening effect does not in this case sensibly increase with the increase of the tension." We have no reason to doubt the truth of this statement when applied to rods subject to tension, but my experiments show that when the rod 000, of soft steel, and the rod 00, of hard steel "drawn to blue," were not subject to such strains, and indeed freed, as far as possible, from all strain, they were *permanently elongated* after they had received their permanent magnetism; and also, that the rod 0, of hard steel "drawn to yellow," had a *permanent retraction* given to it with its permanent magnetic change.

My experiments have been made with such conscientiousness, that at present I am not able to doubt the reality of these effects; but they should be repeated on fresh bars, and this I intend to do at some future day.

It is important that I should here call attention to the fact, that the coefficients I have given in the appended tables are derived from measures on only *one* rod of each species of metal; and it may be that a considerable range in the elongations and retractions may be found in rods made of the same kind of iron or of steel. I hope to be able to present a new series of determinations of these constants, to be made with the apparatus already described, which employs the displacements of Newton's rings as a means of measuring the changes in the longitudinal and transverse dimensions of the rods.

When it is considered that the greatest motions, which have been the objects of my study, have their existence in the space of $\frac{8}{10000}$ths of an inch, while the smallest space within the limits of visibility of the most powerful microscope, being only $\frac{3}{20000}$th (or ·000005) of an inch, and furthermore, when it is known that the last mentioned quantity equals the change in length of one of the rods caused by a variation of temperature of only $\frac{7}{10000}$ths of a degree Centigrade, the difficulties I have conscientiously met and surmounted in this delicate research become manifest; but the very knowledge of those difficulties has tempered with modesty the confidence I feel in my work, and I will gladly accept any correction my measurements may receive from more experienced hands.

ART. XIV.—*On some results of the Earth's Contraction from cooling;* by JAMES D. DANA. Part IV, *Igneous Ejections, Volcanoes.**

IV. IGNEOUS EJECTIONS, VOLCANOES.

THE direct connection of igneous ejections with the movements resulting from the earth's contraction has been briefly illustrated in the course of the remarks on mountain making.† It is apparent, without further discussion, that regions of great disturbances embrace the regions of great igneous ejections; that the oceanic slopes of the border mountains, especially around the Pacific, the greater ocean, have been preëminently subject to such eruptions; and that in Tertiary times, when the earth's crust was becoming too stiff to bend much before the lateral pressure, profound fractures, instead of flexures, were a common result of its action, igneous outflows were most extensive, and volcanoes were of increased size and numbers.

The questions remaining are—

(1.) Does the mobile rock owe its mobility in all cases, or any, to the movements of the rocks under lateral pressure—motion transformed into heat being its source, in conformity with the views ably set forth by Mallet?

(2.) Is the ejecting force in eruptions a result of the same lateral pressure?

1. *Source of igneous fusion.*‡—The suggestion of Prof. Hopkins, with regard to the earth's interior, which has been sustained on a preceding page,§ offers for the source of igneous

* For Part I, see vol. v, p. 423; II, vol. vi, p. 6; III, vol. vi, p. 13.

† This Journal, v, 433, 441, vi, 8, 10.

‡ I say nothing here on the nature or the degree of igneous fusion in plastic rock, as this is foreign to the subject under discussion.

§ Prof. Hopkins's argument from the amount of precession and nutation, in the Trans. Roy. Soc., 1839, 1840, 1842, led him to the conclusion that "the thickness of the solid shell could not be less than about one-fourth or one-fifth of the radius of its external surface." In his paper in the Report of the British Association for 1847, he repeats his conclusion, and then considers the possible steps in the process of refrigeration. Among the different conditions discussed he supposes as one (the one he favors) the temperature of fusion to be increased much by the pressure—at a rate much more rapid than "1° F. for an increase of pressure equivalent to about five atmospheres," and adds that then "we should probably have the condition under which solidification would commence at the center. In this case, after incrustation had begun at the surface, the earth would consist of a solid central nucleus and a solid shell with fluid matter between them, as already explained, till the solidification should be complete." He then remarks, with regard to the present state of our globe, that "under the condition here assumed, with the observed rate of increase of terrestrial temperature in descending, there could be no reasonable doubt of the earth's entire solidity." He next treats more in detail of the process of solidification, and says, having in view the several conditions discussed, that "the incrustation may have constituted the very first step in the solidification, or it may have taken place after the formation of a solid

ejections the old one of viscous rock underneath the earth's crust; but viscous rock at first as a layer, and later as remnants of the same layer, left after the long cooling. This author suggests that these isolated or detached portions may be the source of modern volcanic eruptions, and this view is favored by Scrope, the eminent vulcanologist.*

The theory does not require that the isolated fire-lakes should exist now at the depth of the original viscous layer, for in the movements and flexures of the crust, and the opening of fissures for the escape of the mobile rock, great regions of it may have been pressed up and become isolated fire-lakes at a higher level. Or, as Prof. Hopkins suggests, the subterranean sources of volcanic action may have been in shape like inverted cones extending far up into the crust, and may have finally been divided off into "smaller ones by a process similar to that by which the larger cavities were themselves formed from the general fluid mass, the position of each minor cavity being determined by the points in the roof of the larger one, where previous fractures had left the most perfect volcanic vents." This last explanation holds if regions of volcanic vents date back to early geological time, so that modern volcanoes in an area are successors to indefinitely older ones; but is less applicable where the vents of a region are of Cænozoic origin (as appears to be true of most of them), and a consequence of the later movements of lateral pressure.

The inference that igneous eruptions have generally been derived from a deep-seated source is sustained by the great lithological uniformity of ejections over widely distant ranges of surface. The eruptive rocks (or trap) of the Triassico-Jurassic areas of the Atlantic border, from Nova Scotia to the Carolinas, already many times referred to,† all which belong to

nucleus surrounded by a superficial fluid envelope, according as the solidification began at the surface or center; but in either case, as I have already intimated, the superficial crust when first formed must necessarily have reposed on a fluid mass beneath." He next explains his views as to the formation of the crust, and the final obliteration of the viscous layer; and states, with reference to volcanoes, "By a continuation of this process it is obvious that the superficial crust of our globe must at length arrive at what I conceive, for reasons above assigned [in a paragraph on p. 33 speaking of the isolated sources of volcanoes], to be its present condition, that of a solid mass containing numerous cavities filled with fluid incandescent matter, and either entirely insulated or perhaps communicating in some cases by obstructed channels." These cavities are made the sources of the material of volcanic eruptions.

* Volcanos, 2d ed., 8vo, 264, 268.

† These hills and dikes of "trap" (as they are ordinarily called) have great length and breadth in Nova Scotia. In the Connecticut valley they are very numerous, and in many lines,—as laid down, especially for Connecticut, by Percival in his Geological Report. A copy of a part of his very accurate detailed map of the trap region is reproduced in the writer's Manual of Geology, page 20. At the east and west bend in the dikes, south of the middle of the map, are the Hanging Hills of Meriden, 900 to 1,000 feet high, situated about 20 miles north of New Haven

one epoch, are solely varieties of dolerite: rocks made up essentially of labradorite and pyroxene, with more or less of magnetic iron ore in disseminated grains or crystals. Analyses have shown that the trap of this region in Connecticut and New Jersey is essentially identical in constitution; and an examination and determination of the density of specimens of the same rock from North Carolina and Nova Scotia leave no doubt that it is fundamentally alike throughout. The aspect of the ordinary specimens from these widely distant regions is closely the same, and the density varies little from 3. The dolerite of East Rock, New Haven, Conn., gave Professor G. J. Brush for the specific gravity 3·09—3·085; from West Rock, ib., 3·045—3·07; from the vicinity of Raleigh, North Carolina (a specimen received by the writer from Prof. Kerr of Raleigh, and not distinguishable by the eye from an East or West Rock specimen), 3·16. Prof. Cook of New Jersey obtained for the dolerite of the Palisades (Geol. Rep. N. J., p. 215), 2·94. Prof. H. How gives the writer for a similar variety from Nova Scotia, 2·94. Complete analyses have not been made of many of these rocks. The following are analyses of the West Rock (New Haven) dolerite and that of the Palisades, New Jersey (70 miles west of West Rock), the former by W. G. Mixter, Assistant Chemist in the Sheffield Scientific School, and the latter by Prof. G. H. Cook, of the New Jersey Geological Survey.

	Si	Al	Fe	Mg	Ca	K, Na	ign.
1. West Rock,	52·37	12·31	13·13	6·03	10·74	2·62	0·94 = 98·14
2. Palisades,	53·9	17·5	8·0	10·3	8·0	[2·3]	....=100

There are variations in the dolerite of the regions above referred to, depending on the proportion of the feldspar, and also on the presence of water. But they occur in various parts of the several regions, instead of characterizing any one of them. The dolerite of dikes in East Haven, Conn.—the town adjoining New Haven on the east—diminishes in luster as the dike is more remote from the New Haven line; and in

(and 12 miles from the southern margin of the map); and the range which extends from these hills north continues to Mt. Tom, near Northampton, in Massachusetts. The range to the east, south of this bend, continues southward to Lake Saltonstall, east of New Haven. Other lines cut through the metamorphic rocks; one of these lines of trap ejections in the eastern metamorphic region of Connecticut, as mapped by Percival, extends from Long Island Sound, six miles east of New Haven, nearly to the southern boundary of Massachusetts, over seventy miles, with a nearly east-northeast trend, consisting of an interrupted series of dikes, intersecting metamorphic rocks of various kinds. A second independent Triassico-Jurassic trough exists in Connecticut, 15 to 20 miles west of the main one, over part of the towns of Southbury and Woodbury; and this also has its numerous trap dikes. The Palisades of New Jersey, bordering the Hudson River, are the northern part of a complex series that continues southward and westward through New Jersey and Pennsylvania into Virginia, following the course of the Triassico-Jurassic sandstone areas. There is also a series in the North Carolina area.

the ridges near Saltonstall Lake, two miles distant, it is faintly glistening, and of somewhat less hardness, and, although generally solid throughout, it is in some parts vesicular (amygdaloidal). A precisely similar rock in all its characters occurs among the trap hills (dolerite) of Meriden, called the Hanging Hills, and part of it is amygdaloidal. The same is found also in Nova Scotia. An examination of a specimen from the vicinity of Saltonstall Lake, by Prof. O. D. Allen, shows the presence of 4·53 per cent of matter driven off on ignition, after deducting the hygroscopic moisture (0·60). It indicates the presence of some hydrous mineral (chlorite apparently), in place of part of the augite or feldspar. But the percentage of silica is 49·88, 50·10, according to two determinations by S. T. Tyson of the Sheffield Scientific School laboratory, and thus differs but little from that of the anhydrous dolerite of West Rock and the Palisades; the proportion is less instead of greater. There is hence a close similarity to the other dolerite, notwithstanding the presence of water.

Since the dikes of this hydrated dolerite occur as parts of the same series as the others, and in the same regions, and are of the same epoch and system of ejections, and moreover are exceptional instead of the prevailing kind, it is apparent that the hydrous character is owing to some exceptional condition attending or subsequent to the eruption. The source of liquid rock was all one, and the material must therefore have been essentially one in kind; it could not have been locally hydrous. Portions of the erupted viscid material might have encountered water on the way to the surface, and thus have become penetrated with it;* so that the viscid material at the high temperature became altered in part—some of its augite to chlorite, and perhaps some of its feldspar, with the lime of the augite, to zeolites, etc. Or else, this kind of change may have taken place through infiltrating waters. The fact that the *vesicular* trap (now amygdaloidal), is that which is hydrated, renders it rather probable that while zeolites and calcite may have been later made within the rock by superficial action or

* On this taking in of moisture by liquid rock, Mallet, speaking of the lava in the conduit of a crater, makes the following remarks: "Within a few years it has been proved that capillary infiltration goes on in all porous rocks to enormous depths, and that the capillary passages in such media, though giving free vent to water—and the more as the water is warmer—are, when once filled with liquid, proof against the return through them of gases or vapors. So that the deeply seated walls of the ducts leading to the crater, if of such material, may be red hot and yet continue to pass water from every pore (like the walls of a well in chalk), which is flushed off into steam that cannot return by the way the water came down, and must reach the surface again, if at all, by the duct and crater, overcoming in its way whatever obstructions they may be filled with. And this remarkable property of capillarity sufficiently shows how the lava—fused below or even at or above the level of infiltration—may become interpenetrated throughout its mass by steam bubbles, as it usually but not invariably is found to be."

infiltrating waters, the chief change was cotemporaneous with the eruption; for the vesicular character was undoubtedly then produced, and it was probably dependent on the same moisture that, penetrating the rock, caused the metamorphism or hydration through the mass. Bunsen, in his well known paper on the igneous rocks of Iceland,* gives various facts illustrating this kind of metamorphism yielding chloritic and zeolitic minerals.

There is hence nothing in the relations of the different kinds of dolerite in the Connecticut valley or any part of the Triassico-Jurassic regions of the Atlantic slope, either as to geographical position or chemical composition, that favors the idea of difference of original subterranean source.

Now such a similarity of product occurring at intervals over a region 1,200 miles long, and in several parallel lines, shows some unity of origin. It evinces that the source must have been either the under-crust fire-sea, like the under-Appalachian as we have termed it, derived from the old viscous layer; or else plastic masses within the true crust, which crust, as it was made from the viscous layer by cooling, would have had like uniformity of mineral constitution.

This example of igneous eruption is grand in scale, since the outflows are from tappings along a line more than a thousand miles long; and it may therefore serve well to test the general application of theories of igneous eruptions. It indicates that the original fire-sea was one of great extent.

Professor T. Sterry Hunt, in his paper on "The probable seat of volcanic action,"† and others of earlier date, while adopting the view of a nucleus made solid by pressure and of an exterior crust, with a viscid layer between, has proposed to substitute for the viscous layer recognized as the source of volcanoes by Hopkins, one made by the "aqueo-igneous fusion" of part of the lower sedimentary beds of the supercrust.‡ The alleged cause of such fusion is (1) pressure due to the accumulation of superficial sedimentary beds; (2) increase of heat, by a rise of the isogeothermals—another effect of the same cause; and (3) the presence of moisture, a common feature of sediments: the moisture becoming, under the heating, super-heated vapor, and so aiding by its great dissolving power in the result.

* Pogg. Ann., lxxxiii, 197–272, 1851. The secondary origin of the zeolites and chlorite found to penetrate some dolerite and other kinds of igneous rock, as well as filling the cavities within them, I sustained in an article in vol. xlix of the first series of this Journal (1845); and the various facts I have since observed have tended to confirm me in the conclusion. In the paper referred to, I attribute the change to infiltrating waters. The opinion has many advocates.

† This Journal, II. l, 21, 1870.

‡ I use the term supercrust as it is explained on page 12, that is, for the part of the crust made by the action of exterior agencies over the outer surface of the true crust, the true crust being the part that was formed directly from cooling.

In a later article * he says: "I have taken pains [in former papers] to explain that the deeply buried layers of sediment, together with the superficial and water-impregnated portions of the solid nucleus, constitute a softened or plastic zone from which all plutonic and volcanic rocks proceed, and which allows of the movements observed in the solid crust."

It will be perceived that the hypothetical viscous layer of Hunt lies between a rind made out of sedimentary formations and a solid nucleus which is at surface of sedimentary origin; and the viscous layer which Professor Hopkins regards as belonging to a stage in the process of solidification is supposed to have been closed up, or some way put "hors de combat."

This substitution appears to be quite unnecessary, and the process incapable of producing the result claimed. As has been already explained,† the pressure from the gravitation of sediments cannot produce the heat needed for the fusion, no more than it can cause the plications alleged to attend it. If then no fusion of sediments would have resulted from such a cause, there was no chance for the formation of the deep and extended plastic zone required to meet the demands of the grand system of oscillations the earth's surface has experienced. In fact, the conditions Prof. Hunt's hypothesis appeals to—that is, thick sedimentary accumulations, such as those of the Appalachian region,—are far too local for the production of so vast a plastic zone, even if fusion were a possible result of the accumulation.

Again, the facts mentioned on the preceding page give as positive a declaration against this origin of the material of igneous ejections through the fusion of sediments. The sedimentary strata along the Atlantic border, whether unaltered or metamorphic, deep-seated or superficial, vary every score of miles, and could not yield a uniform quality of fused material for the ejections. In the Connecticut Valley the metamorphic rocks from New Haven, Conn., to northern Massachusetts, a distance of a hundred miles, have *an east-northeast strike obliquely across the region of trap ejections*, and are, on the west side, chloritic mica slate, diabase, chlorite slate, argillite, mica schist, gneiss and other micaceous rocks of various kinds; and the Archæan (Azoic) rocks to the west, in Dutchess Co., N. Y., and in Connecticut west of Winsted, are diverse varieties of gneiss and granitoid gneiss, containing orthoclase and albite or oligoclase with quartz, and sometimes hornblendic, but as far as known without labradorite. Only wide diversity, not uniformity, could come from such varied material. Dolerite is, moreover, the last rock to be looked for from any of it, except it be from the diabase. For it has a low percentage of silica (46 to 52 per cent) and no free quartz, with 8 to 12 per cent of oxide of

* Geological Magazine, Feb., 1868. † This vol., page 13.

iron, about as much of lime and also of magnesia, with very little potash or soda; and in these constituents there is comparatively little variation.

Hunt claims that the presence of moisture in many igneous rocks sustains the idea of derivation from the fusion of sediments, that is, from the fusion of rocks containing water. But it has been shown, (on page 107) that the cases of hydrated dolerite in the region referred to are local and exceptional, and that the ridges are so mixed up with those of the more common anhydrous dolerite, that all must have had one source. His argument would be of some weight if there were no source for the moisture except in the region of fusion. The hydrated rock, moreover, is shown to have the low percentage of silica which belongs to the anhydrous dolerite.

If subterranean fusion were somehow produced and a zone of mobile rock were thus made many scores of miles deep, with the material not simply plastic but of perfect liquidity, and the zone without obstructions in any part so that there could be tidal movements or at least free-flowing currents throughout it, then, if the material entered into fusion were as diverse as the rocks of the Atlantic border, there might be such a mixing up and chemical digestion of limestone and everything else, that the product would perhaps be doleritic—a rock low in silica (or basic). But these conditions are those of the earth's liquid envelope before and after refrigeration began, and of the viscous layer developed out of it, even, probably, to the basic character of the fused material; and further, they are what Hunt's method has no provision whatever for producing.

The facts afforded by other parts of the globe and other periods in its history, add force to this argument. A doleritic or basaltic character is the prevailing one among the igneous eruptions of all ages from Archæan time to the present, and of all continents and oceans. Whitney and Pumpelly have described basic or doleritic rocks of Lower Silurian age from the Lake Superior region, where they are the prevailing igneous rocks. Hunt has described and analyzed others, from Canadian localities, of the Laurentian, the Lower Silurian era and of later Paleozoic time. They are far the most abundant of the igneous products of the Tertiary and Quaternary over the Pacific slope. Similar facts might be cited from other continents.* More than three-fourths of true igneous rocks are probably of this nature. Hence, it is reasonable to pronounce such ejections manifestoes of some kind of community of origin in the earth's ejections, as well as announcements of the kind of ma-

* For comparison with the analyses on page 106, I add here others of the dolerite (trap) of (I) the Giant's Causeway, (II) Staffa, and (III) Färöe, by Streng (Pogg. Ann., xc, 110, 114, 1853), all of which are now supposed to be of Tertiary

terial that constitutes to a large degree the deeper regions of the crust.

There is, however, considerable diversity among true igneous rocks. Besides the prevalent doleritic iron-bearing kinds, including dolerite, peridotite, melaphyre, etc., to which the preceding observations relate, there are trachytic or feldspathic rocks whose constitution, especially in the case of the more siliceous varieties, comports with their origin from the fusion of granitic rocks or of sedimentary beds made of granitic material. They occur in the same regions in which doleritic dikes exist, as well as among volcanic products.

Such a composition does not, however, make it certain that the supercrust was their source, for true granite and gneiss and even quartzites occur constituting old Archæan terranes, and it may be that essentially the same kinds of rock are to some extent represented in regions of the infra-Archæan crust and even in the fire-seas.

Basaltic and trachytic rocks often occur so combined in a single volcanic mountain, that we seem forced to find some other explanation of their origin than that of the fusion of *unlike* sedimentary strata. As long since observed by von Buch at Teneriffe, the center of the mountain may be trachytic when the sides around are basaltic. I found a similar fact in a dissected volcanic mountain of western Oahu.* And at Mauna Loa, where the ejections are almost all basaltic, there are feldspathic lavas at the very summit of the dome about the summit crater. A sight of the boiling movements of Kilauea in 1840 led me to explain this association in volcanic moun-

origin; and another (IV), of an Archæan (Laurentian) dolerite from Grenville, Canada, by Hunt (Geol. Rep. Canada, 1863):

	I. G.=2·88.	II. G.=2·96.	III.	IV.
Silica	52·13	47·80	49·40	50·35
Alumina	14·87	14·80	14·62	17·35
Sesquiox. iron	----	----	----	12·50 [1]
Protox. iron	11·40	13·08	16·27	----
Protox. manganese	0·32	0·09	----	----
Magnesia	6·46	6·84	5·86	4·93
Lime	10·56	12·89	10·34	10·19
Soda	2·60	2·48	2·28	2·28
Potash	0·69	0·86	0·34	0·69
Volatile (H, etc.)	1·19	1·41	2·41	0·75
	100·22	100·25	101·32	99·04

[1] Hunt says the iron is protoxide, though determined under the form of sesquioxide in his analysis.

Lyell recognizes the occurrence of "trap" in all periods from the Laurentian to the present (Principles, chapt. vii); and Mr. S. Allport announces in a recent article (Geol. Mag., May, 1873) entitled "Tertiary and Paleozoic Traps," that he has nearly ready for publication the results of many investigations sustaining the view which he has "for some time maintained, as to the complete identity in composition and structure of eruptive rocks of widely separated geological periods."

* See on this subject the author's Geol. Report, Wilkes Exp. Exped., pp. 204, 269, 368, 372.

tains on the principle of *liquation*—the feldspathic material being the least fusible, and being therefore left at the center while the more fusible iron-bearing lavas were drawn off by the outbreaks through the different sides of the cone. The diversity, on this view, is not proof of diversity of origin

Again, the two kinds of igneous rocks occur on a majestic scale over the Pacific slope of the Rocky Mountains. The trachytic rocks there appear, as stated by Richthofen,* to be generally the older. Clarence King, in his description of the Shoshone Falls on Snake River, states that out of seven hundred feet in thickness of igneous rocks exposed in the bluff, the lower 300 feet are made up of trachyte, while the upper 400 are of basalt; and that a continuous field of igneous rocks, mainly basaltic at surface, stretches over the country of Snake River for three hundred miles or more. The outflows are of later date than the Miocene Tertiary. The fact of the very wide geographical distribution of the basalt on the Pacific slope appears to be good proof, as in the case of the dolerite of the Atlantic border,—but better because of the wider range of the ejections,—that the source of its material was not local, or dependent on the fusion of sedimentary strata. And if this be true of the basaltic rock, it is probably so also of the trachyte. Whatever doubt may exist, the general argument is made a demonstration by the fact explained,† that a vast undercrust fire-sea was a necessity in order that the great heavings and bendings of the earth's crust essential to mountain-making on the Pacific border should have taken place.

The conclusion arrived at militates not only with the theory of Hunt, but also to some extent with Mallet's, unless the latter is made to appeal to the *true crust* for the material to be fused by the motion attending mountain-making. The motion in the true crust, even in the catastrophic period of mountain-making, is very much less and slower than that which is experienced by the plicating strata above it, and must therefore be a much feebler source of heat and fusion. Still, under the fractures, and shovings, and crushings, which must at times take place, it should be sufficient; and, acting at infra-Archæan depths, it would give uniform results over wide areas, or on the other hand a degree of diversity. Unlike Hunt's hypothesis, Mallet gives a reasonable source for the heat occasioning fusion.

But the sufficiency of the method for all cases of igneous ejections may well be questioned. The subsidence ending in

* The Natural System of Volcanic Rocks, Mem. Calif. Acad. Sci., Vol. I, Part 2, 4to, San Francisco, 1868. The trachytes of Auvergne are similarly older than the dolerites of the region. But more recent trachytes occur in Italy, and the rock of modern eruptions in Iceland is trachyte.

† This volume, page 7.

the fissures and trap-ejections of the Atlantic slope from Nova Scotia to North Carolina was extremely slow, and probably nowhere exceeded 5000 feet; and it caused in the end only small displacements of the strata. In such a case as this, the motion would seem to be a wholly inadequate cause of the fusion and ejections. Moreover, if the dependence of the subsidence upon the existence beneath of a great region of mobile rock was a fact, as has been urged,* there was fusion enough without aid from this source.

Further, over the Pacific slope of the Rocky Mountains, the vast ejections in the Tertiary era appear to have had, as I have said, a natural source in an undercrust fire-sea, and the same *that was essential to all the previous oscillations of the crust;* and which, therefore, like that beneath the eastern border of the continent, *must have been continued on from the period of general fluidity.*

Moreover, these Pacific-border eruptions took place in connection with, or as a consequence of, only a slight geanticlinal uplift—that is, slight compared with the extent of the region, although adding 10,000 feet to the height of the Rocky Mountains, since the angle of slope made by it was not over fifteen minutes—and through simple fractures that were unattended by flexings or crushings of the region broken: conditions wholly incapable, it would seem, of generating the heat required for so vast an amount of subterranean fusion as the ejections indicate.

Again, both on the Atlantic and Pacific borders of North America, wherever the plications have been greatest, and the conditions, therefore, favorable for producing the largest amount of heat, there we find evidences of the profoundest metamorphism, and of the *least amount of fissure eruptions;* and, conversely, the regions of gentler plications and feebler metamorphism, or of none, are those of the most numerous fissures and most abundant igneous ejections. The Green Mountains are an example of the former; and the Triassico-Jurassic areas on the Atlantic border, or the Tertiary and Quaternary outflows on the Pacific slope, of the latter. The reverse should be true if the heat for the fusion were transformed motion; for fusion certainly requires a much higher temperature than metamorphism. The evidence appears to be decisive against the making of the vast undercrust fire-sea by this method.

On the other hand, as already stated, there are, in many countries, regions of siliceous trachytes whose ejections may well have come from the local fusion of common granite and the allied schistose rocks, or of sedimentary strata of like composition.

* This volume, page 7, and beyond.

Mallet's theory presents us with a true cause; but what are the limits of its action it is very difficult to decide. It relieves the theory of local fire-seas as derivative from the old viscous layer of the chief objection urged against it—that such isolated fire-regions could not long exist surrounded by cooled rock; for, if inadequate to make great undercrust fire-seas one or more thousand miles in length, like the Appalachian, the cause may be sufficient through the generated heat to keep the old fire-seas in prolonged existence.

2. *What are igneous rocks?*—From the preceding discussion we derive an idea of the distinction between eruptive and metamorphic rocks. Since the larger part of eruptive rocks have come from the infra-Archæan region—either the true crust, or the fire-seas within or below it—they are igneous in all their history, and in no sense metamorphosed sediments, whether derived from a second fusion of the rocks where they originated or not.

Again, the plastic rock-material that may be derived from the fusion or semi-fusion of the supercrust, (that is, of rocks originally of sedimentary origin,) gives rise to "igneous" rocks often not distinguishable from other igneous rocks, when it is ejected through fissures far from its place of origin; while crystalline rocks are simply *metamorphic* if they remain in their original relations to the associated rocks, or nearly so.

Between these latter igneous rocks and the metamorphic there may be indefinite gradations, as claimed by Hunt. But if our reasonings are right, the great part of igneous rocks can be proved to have had no such supercrust origin. The argument from the presence of moisture or of hydrous minerals in such rocks in favor of their origin from the fusion of sediments has been shown to be invalid.

3. *Source of the ejecting force.*—When the fractures of the crust giving exit to fissure eruptions are a direct sequence to a long continued subsidence—as, for example, in the case of the Triassico-Jurassic eruptions of the Atlantic border,—there can hardly be a doubt that the lateral pressure causing the subsidence contributed also to the ejection of the plastic rock from beneath. And as the great fissurings of the crust are in all cases incidents in the working of lateral pressure, it is unsafe to deny that this cause has not aided in the great majority of eruptions in non-volcanic regions.

Another cause of ejection appealed to is pressure from the vapors imprisoned in the regions of fused rock. It must have often given efficient aid. But such vapors may not exist to the extent sometimes supposed about the deep sources of the material of fissure eruptions. Non-volcanic igneous rocks are

usually solid throughout, without the minutest vesicle, and similar complete compactness characterizes many fissure ejections even of volcanic regions, when they have taken place at a considerable distance from the volcanic vent.* This would hardly be so generally the fact if vapors were abundant about the sources of the ejected material, for such vapors would imply the existence in the mobile rock itself ordinarily of vaporizable ingredients capable of easy vaporization under the pressure there existing. The fact seems to be that the great pressure is in the way of vaporization of the sulphids that may exist in the plastic material; for pyrites is often found in the solid basalt. And, further, the deep-seated sources of igneous rocks must be mostly or wholly below the regions accessible to moisture; for if not they would show its presence by hydration and frequently a vesicular structure.

Volcanoes, in their states of *ordinary* activity and eruption, do not appear to be dependent on the lateral pressure in the earth's crust. As I have long since urged, sustaining the view of Prévost, the force engaged is chiefly pressure from the expansion of vaporizable material rising with the lava. Besides this, there is the hydrostatic pressure of the liquid column raised in the conduit through the expanding vapors. The want of sympathy between the summit crater of Mauna Loa, nearly 14,000 feet in elevation, and the larger crater of Kilauea on the flanks of the same broad mountain only 4000 feet above the sea, I have adduced as evidence that the ordinary volcanic action was here due to movements in the upper parts of the lava columns, probably to portions extending little below the sea-level, and that these volcanoes were therefore mainly dependent for their various phases on the freshwaters precipitated over the mountain slopes. The waters of the ocean take their part in such action; but they are not in Hawaii the chief source of activity.† The effects of hydrostatic pressure have been exemplified in the same volcanic mountain, not only in fractures of the mountain, but also in majestic fire-fountains, in which the lavas were thrown to heights from 100 to 700 feet.‡

Another Part, on the formation of the Continental plateaus and Oceanic depression, will finish this memoir.

* It is a great, though common, mistake to suppose that volcanic ejections are slags or scoria. The surface of an outflow is often of this character for a depth of six inches or perhaps a foot. But below this, the layer is usually a compact stony mass with nothing slag-like except that it is somewhat vesicular. About Hawaii part of the rock is as solid and free from vesicles as the dolerite of the Connecticut Valley.

† See further on these points the author's Expl. Exp. Geol. Report, and also various articles in this Journal. Mallet's memoir, already often referred to, has excellent observations on this subject, as on others connected with volcanic action.

‡ This Journal, II, xiv, 219, 254, 1852.

ART. XV.—*Researches on the Hexatomic compounds of Cobalt;** by WOLCOTT GIBBS.

IN the joint memoir of Genth and myself on the ammonia-cobalt bases it was stated that Xanthocobalt is not the only product of the action of nitrous acid gas upon ammoniacal solutions of cobalt. A further investigation of this and other related subjects was then promised. I propose now to resume the study of this class of compounds from the standpoint of the chemistry of the present day. The progress of science has rendered necessary the abandonment of my former theoretical views, as well as the adoption of the new notation. It has also, as I shall endeavor to show, lent a peculiar interest to the study of the ammonia-metallic bases.

In studying the action of the alkaline nitrites upon salts of cobalt, or upon those of the different series of ammonia-cobalt compounds, a principal difficulty arises from the varying nature and relative proportions of the products obtained under various conditions of temperature, concentration of solutions employed and duration of action. I have endeavored to cover the whole ground as completely as possible.

1. *Action of ammonia and ammonic nitrite upon a solution of cobaltic chloride and ammonic nitrate.*—When a warm solution of cobaltic chloride, $CoCl_2$, is mixed with ammonic nitrate, and then with a solution of ammonic nitrite, containing much free ammonia, the solution soon becomes deep orange, and after 24 hours deposits orange-brown crystals in large quantity. The mother liquor of these crystals is olive-green. By re-solution in hot water containing a few drops of acetic acid, and filtration, beautiful orange-yellow needles may be obtained as this filtrate cools. The crystals are perfectly free from chlorine and represent the nitrate of a new series of ammonia-cobalt salts, the formula of the salts being

$$Co_2(NH_3)_8(NO_2)_4(NO_3)_2.$$

The formation of this salt is accompanied by an absorption of oxygen from the air and may be expressed by the equation:

$$2CoCl_2+2NH_4.NO_3+8NH_3+4NH_4.NO_2+O=Co_2(NH_3)_8(NO_2)_4(NO_3)_2+4NH_4Cl+2(NH_4)_2O.$$

2. *Action of a mixture of ammonia and potassic nitrite upon cobaltic sulphate.*—When cobaltic sulphate is dissolved in water and a mixture of ammonia and potassic nitrite is added, the liquid speedily becomes brown upon the surface, and after a few hours orange-yellow crystals form upon the bottom and sides

*Being Part II of Researches on the Ammonia-cobalt bases, by Wolcott Gibbs and F. A. Genth.

of the containing vessel, while a green flaky matter is at the same time deposited. When large quantities of material are operated upon, the complete oxidation requires several days. On filtering, a bright green mass mixed with orange-yellow crystals remains upon the filter; the filtrate is olive-green, and on standing often deposits small brilliant orange-yellow scales. If the mass on the filter is treated with hot, very dilute, sulphuric acid, it instantly becomes bright orange and on boiling dissolves. The solution then deposits on cooling a splendid salt, which has the formula

$$Co_2(NH_3)_8(NO_2)_4SO_4$$

and which is the sulphate corresponding to the nitrate already mentioned.

3. *Action of a mixture of ammonia and potassic nitrite upon cobaltic nitrate.*—When cobaltic nitrate is dissolved in water and a mixture of ammonia and potassic nitrite is added, the liquid speedily becomes brownish-orange, and after an hour begins to deposit bright orange-yellow crystals, mixed with a green flocky matter, precisely as in the case of the sulphate. By dissolving the orange-yellow crystals in boiling water, a few drops of acetic acid being added to prevent decomposition, a fine sherry-wine colored solution is obtained, which on cooling deposits crystals of two different forms, the larger portion being in octahedrons, the smaller in prismatic forms. By careful mechanical separation and recrystallization these crystals may be separated and the two salts obtained pure for analysis. In this manner I found the octahedral salt to be nitrate of Xanthocobalt, while the prismatic crystals are the nitrate of the octamin series above mentioned. In one experiment:

0·3833 gr. gave 0·1890 gr. $CoSO_4$ = 18·77 pr. ct. cobalt.

The formula of nitrate of Xanthocobalt, $Co_2(NH_3)_{10}(NO_2)_2(NO_3)_4$, requires 18·73 pr. ct.

0·7369 gr. gave 0·4050 gr. $CoSO_4$ = 20·92 pr. ct. cobalt.

The formula of the nitrate of the new series, $Co_2(NH_3)8(NO_2)4(NO_3)_2$, requires 20·99 pr. ct.

For greater certainty I made also a nitrogen determination in this nitrate:

0·5668 gr. gave 168·5 c.c. nitrogen at 13°·5 C and 756·1^{mm} = 34·79 pr. ct. nitrogen.

The formula cited requires 34·88 pr. ct. The two salts were further readily recognized by their characteristic reactions. In my experiments the proportion of Xanthocobalt salt found was much the greater. The formation of the new nitrate may in this case be represented by the equation

$$2Co(NO_3)_2+8NH_3+4KNO_2+OH_2+O=Co_2(NH_3)_8(NO_2)4(NO_3)_2+2KNO_3+2OKH.$$

and the formation of the nitrate of Xanthocobalt by the equation:

$$2Co(NO_3)_2+10NH_3+2KNO_2+OH_2+O=Co_2(NH_3)_{10}(NO_2)_2(NO_3)_4+2OKH.$$

The green flocky matter which accompanies the formation of the above mentioned nitrates and sulphate is cobaltic hydrate, $Co(OH)_2+2OH_2$, and is of course due to the action of the potassic hydrate upon the solution of cobalt in excess. I varied the above process by adding ammonia first to the solution of cobaltic nitrate, and afterward the solution of potassic nitrite, but the results were the same.

4. *Action of ammonia and potassic nitrite upon a mixture of cobaltic and ammonic sulphates.*—In this case as in the others the solution becomes brown and deposits an orange crystalline mass. If the mass is dissolved in water and a solution of potassic bromide is added, after standing, fine crystals are formed, which after a single recrystallization are pure bromide of Xanthocobalt. In one experiment:

0·5634 gr. gave 0·2496 gr. $CoSO_4$ = 16·87 pr. ct. cobalt.
0·7294 gr. gave 0·4496 gr. silver = 45·65 pr. ct. bromine.

The formula, $Co_2(NH_3)_{10}(NO_2)_2Br_4$, requires cobalt 16·86; bromine 45·71. I did not succeed in finding the sulphate of the octamin series among the products in the single experiment which I made with the above mentioned mixture. If present at all its relative quantity must have been small. The formation of sulphate of Xanthocobalt is easily explained by the equation:

$$2.CoSO_4+10NH_3+2KNO_2+OH_2+O=Co_2(NH_3)_{10}(NO_2)2(SO_4)_2+2OKH.$$

but it is not easy to see why the presence of ammonic sulphate should determine the production of sulphate of Xanthocobalt in place of the sulphate of the octamin series.

With these preliminaries I pass to the description of the salts of the new octamin series. These salts as a class greatly resemble those of Xanthocobalt, but are rather more stable. They have a fine sherry-wine color, are usually comparatively insoluble in cold, and are dissolved with difficulty even by boiling water. The solutions when neutral are decomposed by boiling, ammonia being evolved and a black powder precipitated. The addition of a small quantity of acetic acid serves to prevent the decomposition in hot solutions. Mineral acids, even in small quantity, usually produce more or less decomposition on heating. The salts crystallize with remarkable facility, resembling in this respect the salts of Luteocobalt which are, however, much more soluble. As the octamin salts are easily prepared in quantity, they may hereafter be found to

possess some value as means of investigation from their remarkable power of crystallization.

Sulphate.—Of all the salts of this series the sulphate is that which is most easily prepared in quantity and free from other products. The general method of preparation has been already pointed out. The mixture of cobaltic hydrate and crude sulphate is to be boiled in very dilute sulphuric acid, filtered, and the solution allowed to stand for a few hours, when the sulphate separates almost completely, in consequence of its insolubility in cold water. The mother liquor contains a large quantity of cobaltic sulphate, and traces of the new salt together with potassic and ammonic sulphates. A second crystallization gives a perfectly pure salt. In large crystals the salt has a dark wine-red color, like the salts of Xanthocobalt. It usually separates from hot concentrated solutions in small, very brilliant, yellow scales which under the microscope appear to belong to the quadratic system. The sulphate is remarkable for its insolubility. Cold water dissolves a very small quantity, the solution taking a golden-yellow color. Even in boiling water the salt is but slightly soluble; but dilute sulphuric acid dissolves it more readily and without decomposition if the boiling be not continued too long. Stronger acid readily decomposes the sulphate by boiling When boiled for some time with dilute chlorhydric acid, the solution gradually becomes violet-red, and on cooling deposits crystals of chloride of Purpureocobalt. Of these crystals,

0·2825 gr. gave 0·1749 gr. $CoSO_4$=23·56 pr. ct. cobalt.

The formula $Co_2(NH_3)_{10}Cl_6$ requires 23·55 pr. ct.

The decomposition is accompanied by effervescence from the escape of gas, apparently nitrogen mixed with a smaller quantity of nitrous acid vapors, and may perhaps be expressed by the equation

$$2Co_2(NH_3)_8(NO_2)_4SO_4=Co_2(NH_3)_{10}Cl_6+2CoSO_4+12OH_2+2NO_2+12N.$$

In this reaction we pass from a lower to a higher ammonia-base, and Genth and I have shown that we may also pass from Purpureocobalt to Luteocobalt, or from the decamin to the dodecamin series, the higher term being in each case the product of the decomposition of the lower. The formula of the sulphate in the new series is, as stated, $Co_2(NH_3)_8(NO_2)_4SO_4$. The following are the direct results of analysis:

0·6142 gr. gave 0·3596 gr. $CoSO_4$=22·28 pr. ct. cobalt.
0·4207 gr. gave 0·2454 gr. " =22·21 " "
1·5547 gr. gave 0·6785 gr. $BaSO_4$=17·98 " SO_4
0·6960 gr. gave 0·2903 gr. water = 4·63 " hydrogen.
0·4693 gr. gave 123·5 c. c. nitrogen at 9°·5 C. and 754·5^{mm}=31·33 per cent.

			Calculated.	Found.
Cobalt	2	118	22·09	22·28 22·21
SO_4	1	96	17·97	17.98
Hydrogen	24	24	4·49	4·63
Nitrogen	12	168	31·46	31·33
Oxygen	8	128	23·99	----
		534	100·00	

On Blomstrand's view of the constitution of the ammonia-metallic bases, the formula of the sulphate may be written :

$$\overset{vi}{Co_2}\left\{\begin{matrix}NH_3-NO_2\\NH_3-NO_2\\NH_3-NH_3\\NH_3-NH_3\\NH_3-NO_2\\NH_3-NO_2\end{matrix}\right\}>SO_4$$

I shall discuss this view more fully at the close of this paper.

Chloride.—The chloride of this series cannot be readily obtained by the action of a mixture of ammonia and potassic nitrite upon cobaltic chloride, since, as I shall show hereafter, other products are formed under these circumstances in much the larger quantities, salts of Xanthocobalt predominating. It may, however, be easily prepared in quantity by boiling the crude sulphate with baric chloride and a very small quantity of chlorhydric acid. To avoid loss, the baric sulphate must be repeatedly and carefully washed with boiling water and a trace of free acid. The chloride then crystallizes from the filtrate in beautiful iridescent crystals. The forms of these crystals together with those of other salts of this series I hope hereafter to be able to give in detail. The chloride has the characteristic sherry-wine color of the salts of this series, and the small crystals are very brilliant and exhibit a remarkable iridescence.

The chloride is more soluble than the sulphate, but still belongs to the class of slightly soluble salts, and crystallizes almost completely from hot solutions as these become cold. The salt possesses in a high degree the sharply defined crystalline character of the members of this series, and forms a large number of compounds with metallic chlorides, many of which are of great beauty. The constitution of the chloride is represented by the formula

$$Co_2(NH_3)_8(NO_2)_4Cl_2$$

as the following analyses show:

0·5164 gr. gave 0·3152 gr. $CoSO_4$=23·24 pr. ct. cobalt.
0·6048 gr. gave 0·3683 gr. $CoSO_4$=23·18 " "
0·7188 gr. gave 0·3027 gr. silver =13·84 " chlorine.
0·4846 gr. gave 0·2152 gr. water = 4·92 " hydrogen.
0·6160 gr. gave 172·5 c. c. nitrogen at 16° C. and 768·2^{mm}=32·91 per cent.

			Calculated.	Found.
Cobalt	2	118	23·18	23·18 23·24
Chlorine	2	71	13·94	13·84
Hydrogen	24	24	4·71	4·90
Nitrogen	12	168	33·00	32·91
Oxygen	8	128	25·17	----
		509	100·00	

The corresponding bromide, $Co_2(NH_3)_8(NO_2)_4Br_2$, resembles the chloride so closely that no special description is necessary. In this salt,

0·3944 gr. gave 0·2059 gr. $CoSO_4$=19·87.

The formula requires 19·73 per cent.

Hyperiodide.—When a solution of iodine in potassic iodide is added to one of the nitrate of this series, a magnificent crystalline cinnabar-red compound is precipitated, which may be washed with cold water and afterward with a little alcohol without decomposition. For analysis, the salt was dried in pleno over sulphuric acid. The crystals are small scales of unusual beauty and richness of color. They are slightly soluble in cold water, and are partially decomposed by boiling water with evolution of iodine vapors. Even long boiling, however, does not appear to decompose them completely. When heated with a solution of sodic sulphite the salt instantly becomes yellow and is converted into the normal iodide. No similar compound is formed when a solution of potassic hyperiodide is added to one of nitrate of Xanthocobalt. The formation of the hyperiodide may be represented by the equation:

$$Co_2(NH_3)_8(NO_2)_4(NO_3)_2+2KI_3=Co_2(NH_3)_8(NO_2)_4I_6+2KNO_3$$

In this salt,

0·5748 gr. gave 0·1494 gr. $Co.SO_4$= 9·87 pr. ct. cobalt.
0·4705 gr. gave 0·2550 gr. silver =63·70 " iodine.
0·3942 gr. gave 49 c. c. nitrogen at 14·5° C, and 736·8^{mm}=14·10 per cent nitrogen.

			Calculated.	Found.
Cobalt	2	118	9·83	9·87
Iodine	6	762	63·50	63·70
Nitrogen	12	168	14·00	14·10
Hydrogen	24	24	2·00	----
Oxygen	86	128	10·67	----
		1200	100·00	

If we consider iodine as triatomic in this salt its constitutional formula may be more simply represented by the expression:

$$Co_2^{vi}\begin{cases}NH_3=I-NO_2\\NH_3=I-NO_2\\NH_3=NH_3-I\\NH_3=NH_3-I\\NH_3=I-NO_2\\NH_3=I-NO_2\end{cases}$$

Nitrate.—I have already stated that the nitrate of this series may be formed by the action of a mixture of ammonia and ammonic nitrate upon a solution of cobaltic chloride and ammonic nitrate. It is much more convenient, however, to prepare it from the crude sulphate by double decomposition with baric nitrate. The sulphate is to be boiled with a small excess of baric nitrate and a little acetic acid and the baric sulphate carefully washed to avoid loss of nitrate. From the filtered solution the new nitrate crystallizes almost completely on cooling in beautiful orange-yellow needles, and sometimes in distinct prismatic forms. It is much more soluble than the sulphate, though cold water takes up but little. Boiling water and dilute acid solutions dissolve it more readily. The reactions of the base may be studied most conveniently with this salt. The formula of the nitrate is

$$Co_2(NH_3)_8(NO_2)_4(NO_3)_2$$

as the following analyses show:

0·2405 gr. gave 0·1333 gr. $CoSO_4$ = 21·10 per cent cobalt.
0·6564 gr. gave 0·2484 gr. water = 4·21 per cent hydrogen.
0·6148 gr. gave 173·5 c.c. nitrogen at 4°·5 C. and 762·2^{mm}·=34·83 %.

			Calculated.	Found.
Cobalt	2	118	20·99	21·10
Hydrogen	24	24	4·27	4·21
Nitrogen	14	196	34·88	34·83
Oxygen	14	224	39·86	
		562	100·00	

The nitrate explodes, though not very violently, on being heated. Its solution gives with a potassic ferrocyanide no precipitate at first, but after some hours beautiful garnet-red acicular crystals are formed. It is most easily distinguished from the nitrate of Xanthocobalt by its crystalline form and by the extremely characteristic precipitates which its solution yields with potassic hyperiodide and with potassic chromate.

Chromate.—When a solution of potassic chromate is added to one of the nitrate of the octamin series a most beautiful lemon-yellow salt is formed, which separates almost immediately in very brilliant scales which appear to belong to the quadratic system, and to be isomorphous with the sulphate. The salt is but slightly soluble in water. Its marked crystalline form renders it valuable as distinguishing the salts of this series from those of Xanthocobalt. In this salt,

0·4660 gr. gave 0·2128 gr. $BaCrO_4$ = 20·95 per cent CrO_4.
0·4659 gave 119·5 c.c nitrogen at 9·75° C. and 753·5^{mm}=30·42 %.

The formula, $Co_2(NH_3)_8(NO_4)_4CrO_4$, requires 20·97 per cent CrO_4 and 30·42 per cent of nitrogen.

Dichromate.—This salt is easily formed by adding a solution of potassic dichromate to one of the octamin nitrate. It separates after a few minutes in beautiful orange-yellow needles which may be redissolved and again crystallized without decomposition. In appearance and solubility it can hardly be distinguished from the corresponding salt of Xanthocobalt,

$$Co_2(NH_3)_{10}(NO_2)_2(Cr_2O_7)_2 + 2OH_2.$$

The formula of this salt is

$$Co_2(NH_3)_8(NO_2)_2Cr_2O_7.$$

0·5604 gr. gave 0·4315 gr. $BaCrO_4$ = 32·91 per cent Cr_2O_7.

The formula requires 33·06 per cent. The determination of CrO_4 and Cr_2O_7, in this and similar compounds containing NO_2, can be effected more accurately by means of a baric salt than by mercurous nitrate, since the nitrous compound always reduces a little chromic acid to chromic sesquioxide.

Platino-chloride.—A solution of sodic platino-chloride, $PtCl_6Na_2$, produces in one of the new nitrate after a time fine orange-brown prismatic crystals which, however, cannot very well be recrystallized without decomposition. The crystals were washed with cold water, dried by pressure and then over sulphuric acid. The analysis was made by boiling the salt with zinc and dilute sulphuric acid, filtering off, and weighing the reduced platinum and determining the chlorine in the filtrate by silver. In another portion of the salt the platinum and cobalt were determined together by gentle ignition in a current of hydrogen gas. In this manner

0·3959 gr. gave 0·0921 gr. platinum and 0·3016 gr. silver = 23·26 per cent platinum and 25·04 per cent chlorine.

0·4459 gr. gave 0·1652 gr. platinum and cobalt = 37·04 per cent. Subtracting 23·26 per cent platinum from this we have 13·78 per cent cobalt.

		Calculated.	Found.
Cobalt	2	13·91	13·78
Chlorine	6	25·12	25·04
Platinum	1	23·23	23·26

The formula of this salt is therefore

$$Co_2(NH_3)_8(NO_2)_4Cl_2 + PtCl_4.$$

Auro-chloride.—A solution of auro-chloride of sodium, $AuCl_4Na$, produces immediately in one of the octamin nitrate a beautiful nearly crystalline precipitate, with a fine canary-yellow color and silky luster. Small quantities of this salt may be dissolved in boiling water without decomposition, but it is very difficult to recrystallize it without great loss from the reduction of the gold. When boiled for a short time the salt is almost completely decomposed. It is remarkably insoluble in cold water. For analysis the salt was dried on bibulous paper, and afterward in pleno over sulphuric acid. The analysis was

effected by boiling the salt with zinc as in the case of the platinum salt, and determining the chlorine in the filtrate by silver, but the gold precipitated was found to contain much metallic cobalt. Another analysis was made by simply heating with sulphuric acid, precisely as in the process which Genth and myself introduced for the determination of cobalt in these salts and then washing and weighing the gold. This method was found to give excellent results. In this manner,

0·4791 gr. gave 0·3697 gr. silver = 25·36 per cent chlorine.
0·3942 gr. gave 0·2483 gr. Au + $CoSO_4$ = 0·1391 gr. gold, and by difference 0·1092 gr. $CoSO_4$ = 10·54 per cent cobalt and 35·30 per cent gold.

		Calculated.	Found.
Cobalt	2	10·57	10·54
Gold	2	35·30	35·30
Chlorine	8	25·44	25·36

The formula of the salt is therefore

$$Co_2(NH_3)_8(NO_2)_4Cl_2 + 2AuCl_3.$$

Erdmann's Salt.—O. L. Erdmann* in 1866, described a remarkable salt which is formed when a solution of potassic nitrite is added to a solution of cobaltic chloride containing an excess of ammonic chloride. The liquid quickly assumes a dark orange color, becomes strongly acid and evolves red vapors. After a time very beautiful oblique rhombic crystals are deposited which, according to Erdmann, have the formula (old style) $Co_2O_3 2NH_3, 3NO_3 + KO, NO_3$.

In modern notation the formula of Erdmann's salt may be written $Co_2(NH_3)_4(NO_2)_8K_2$.

Erdmann states that the potassium in this salt may be replaced by other metals, and describes the corresponding ammonium and silver salts. These compounds are especially interesting, because they hold an intermediate position between the two series represented respectively by the terms

$$Co_2(NH_3)_{12}Cl_6 \text{ and } Co_2(NO_2)_{12}K_6.$$

I propose therefore to speak of them more in detail hereafter, and to confine myself at present to their relations to the salts of the octamin series.

When a solution of Erdmann's salt, $Co_2(NH_3)_4(NO_2)_8K_2$, is added to one of the octamin nitrate, a beautiful crystalline precipitate is formed, which after washing with cold water may be redissolved in hot water and then separates in fine orange-yellow granular crystals. The equation representing the reaction is here

$$Co_2(NH_3)_8(NO_2)_4(NO_3)_2 + Co_2(NH_3)_4(NO_2)_8K_2 = 2KNO_3 + Co_2(NH_3)_4(NO_2)_8(Co_2(NH_3)_8(NO_2)_4)''.$$

* Journal für prakt. Chemie, xcvii, 385.

The new salt gives with reagents the reactions of the salts of the octamin series. The relation between the two complex atoms which form a molecule of the new salt is worthy of notice, the number of atoms of ammonia and nitroxyl in the one corresponding to the number of atoms of nitroxyl, NO_2, and of ammonia in the other; one complex atom being, to use Graham's convenient expression, chlorous and the other zincous. We have furthermore the relation expressed by the equation:

$$Co_2(NH_3)_4(NO_2)_8(Co_2(NH_3)_8(NO_2)_4)=2Co_2(NH_3)_6(NO_2)_6.$$

Now I shall show, farther on, that there exist several other salts, the empirical constitutions of which may be represented also by multiples of the formula

$$Co_2(NH_3)_6(NO_2)_6,$$

so that we have here, for the first time, I believe, in inorganic chemistry, a series of strictly metameric bodies. In the salt of the octamin series:

0·2600 gr. gave 0·1622 gr. Co 304=23·74 per cent cobalt.

The formula requires 23·79 per cent.

The salts which I have described are not the only ones which contain 8 atoms of ammonia with 2 atoms of cobalt. In our memoir Genth and I made mention of a leek-green crystalline body which we obtained in more than one reaction in quantities too small for analysis, and which we termed, provisionally, Praseocobalt. Braun subsequently denied the existence of any such substance, but in an excellent paper on the ammonia-cobalt compounds, F. Rose has not merely described and analyzed the body in question, but has given a method of preparing it in quantity. Rose gives for the formula of this salt $Co_2Cl_3N_4H_{12}$ (old style). I should write this

$$Co_2(NH_3)_8Cl_6,$$

and give it the atomistic formula

$$Co_2\begin{cases}NH_3-Cl\\NH_3-Cl\\NH_3-NH_3-Cl\\NH_3-NH_3-Cl\\NH_3-Cl\\NH_3-Cl\end{cases}$$

It thus forms the type of a special octamin series, the relations of which to the salts which I have described are easily seen by comparing the formulas which I have given. Rose has not described any other salts of this series. It seems possible that my series may be derived from this by acting upon the chloride with argentic nitrite; we may have

$$Co_2(NH_3)_8Cl_6+4AgNO_2=Co_2(NH_3)_8(NO_2)_4Cl_2+4AgCl,$$

but I have as yet made no experiments in this direction. Finally Künzel* described, many years since, a hyposulphate, to which he gave the formula $Co_2O_3+4NH_3+2S_2O_5$ (old style). This formula becomes in my view, $Co_2(NH_3)_8S_2O_{13}$ and the salt then belongs to the octamin series, but I am unable to assign to it any plausible atomistic expression, and it is possible that its empirical constitution has not yet been correctly given.

In treating of the salts of my new series it appeared to me more in accordance with the theoretical views which I have adopted to abstain from trivial names. All the members of this series may however be regarded as containing the complex atom $Co_2(NH_3)_8(NO_2)_4$, which alone is constant and which from one point of view may be regarded as a diatomic radical or residue, and those who justify the use of trivial names by their convenience may find the name "Croceocobalt" expressive and appropriate.

(To be continued.)

Cambridge, June 16th, 1873.

ART. XVI.—*Mineralogical Notes on Utah, California and Nevada, with a description of Priceite, a new Borate of Lime;* by B. SILLIMAN.

1. *Enargite*, $3CuS+As^2Sb^3$.—This hitherto rare mineral exists in two or three localities in a district of Southern Utah, known as the Tintic District, about eighty miles south of Salt Lake City. The localities are, (1) the Shoebridge Mine, (2) the Mammoth vein, Eureka Hill, East Tintic, and, (3) the Dragon Mine, East Tintic. All these localities occur in metamorphic crystalline rocks of the granitic family.

The Shoebridge locality furnishes finely crystallized specimens, associated with octahedral pyrite. The vein in which it is found fills a fissure about four feet wide in granitic rocks. This vertical fissure is filled to the depth of about 80 feet from surface with enargite mixed with pyrite. The whole mass is regarded as a silver ore. A sample of the ore made up from such stock as I had in hand yielded to fire assay 269·25 oz. troy of silver, or $347.34 to the ton of 2000 lbs.; this is equal to 0·841 per cent of silver, which is considerably above the average value of the vein. Below the depth of 80 feet, the character of the vein changes, as I am informed by one of the owners, Mr. Samuel T. Hatch, of Salt Lake City, to a vein of argentiferous galena, carrying some antimony. In examining many hundred

* Journal für prakt. Chemie, lxxii, 218.

pounds of the ore taken from above the galena zone, I found only enargite and pyrite with quartz and some heavy spar as a gangue—and not a trace of galena, as the analysis proves.

The enargite from Shoebridge mine cannot be distinguished by the eye from that which was first mentioned by the late Prof. Root, from the "Morning Star Mine" in Alpine County, California (this Journal, II, xlvi, 201).* It occurs both massive of a brilliant luster and fracture, resembling in color gray copper; and also in brilliant orthorhombic crystals striated on the terminal plans parallel to the longer diagonal. The crystals are sometimes 5 or 6mm. long, but more commonly are not over 2mm. in length. The forms are more simple than the crystals figured from Peru. Dr. Gideon E. Moore, who has studied those from the Morning Star Mine, informs me that their form is identical with the Shoebridge mineral, and is expressed by the crystallographic formula $\infty P . 0P . \infty \breve{P} \infty . \infty \breve{P} \infty$.

Its pyrognostic characters conform to those of the Peruvian mineral, but it contains much less antimony then the California variety. Its specific gravity is 4·861 in fragments to 5·111 solid—almost that of pyrite, and somewhat higher than the Peruvian variety. Mr. E. S. Dana kindly furnished me some time ago the following approximate analysis of the Shoebridge mineral made by the chlorine method upon carefully selected crystals. He obtained—

Sulphur	34·35	Iron	1·06
Antimony	·95	Zinc	*trace*
Arsenic	17·20	Residue (undissolved),	*trace*
Copper	46·94		100·50

The silver was not determined. The iron is probably due to the pyrite, with which the species enargite is intimately associated; this occasions also the excess of sulphur, in the analysis, which corresponds, however, sufficiently well with the formula given above.

At the "Mammoth Vein," in Eureka Hill, the enargite occurs in broad laminated masses somewhat resembling black hornblende, and stained green in the joints by the oxidation of a portion of the copper. It is associated with calcite and is quite free from pyrite. The blowpipe shows it to be free, or nearly so, from antimony. This locality has not furnished the enargite otherwise than in columnar and cleavable masses.

The mineral from Dragon Mine resembles the last named variety, but is more massive. Neither of the two latter varieties have been analyzed.

2. *Bismuthinite*, B^2S^3.—This species is found rather abundantly in three associated mineral veins in Granite Min-

* Wrongly quoted in Dana (5th ed.), p. 797, as in vol. xlv.

ing District, Beaver County, Utah, about ten miles west of Beaver City. The main vein, which is said to be about six feet in thickness, contains also bismuth ocher or *bismite*, $\dot{B}i$, staining the surface greenish yellow (a sign by which the vein has been traced at intervals, it is said, for about 2000 feet), and *bismutite* (hydrous carbonate of bismuth), $\dot{B}i^4\dot{C}^3H^4$, in yellowish-gray masses inclining to siskin-green. These last two species are due, no doubt, to the oxidation of the bismuthinite.

These three species sometimes form masses of considerable size, but more commonly the sulphid occurs alone in a gangue of almadin garnet of a hair-brown color, with black hornblende, heavy spar and quartz. Yellow pyrite exists in small quantity in the gangue, and by its oxidation has furnished masses of iron oxides. No arsenical ores could be detected in the samples which have fallen under my observation, nor does the blowpipe detect either lead, antimony or copper.

Hitherto bismuthinite has been a rare species in N. America, and I do not know that it has before been found in quantity likely to give it a commercial value.* In the Beaver vein, the metal is said to form about five per cent of the mass.

When this locality is properly opened for mining we may hope to obtain an abundance of good mineralogical specimens of these several species. I am indebted to Mr. J. B. Meader of Salt Lake, and to Col. Head of San Francisco, for the specimens from Beaver, which I have examined.

3. *Wulfenite.*—In a former communication (this Journ., III, iii, 195) I pointed out the absence, so far as observed, of phosphates among the mineral species found in the Wahsatch Range, and the existence of molybdic acid as wulfenite in its place. Further observation has confirmed this statement. In a subsequent visit to that region, and more recently, I have received from Major Wilkes, of Salt Lake City, wulfenite from the Empire mine, Lucin District, Box-Elder County, Utah, in the Wahsatch Range, which for beauty is rarely equalled by the same species from any known locality. The crystals are thin tables 20 to 30^{mm}. broad, of a pure yellow color set on a deep brown iron ochre, and making splendid cabinet specimens.

4. *Orpiment and Realgar.*—These two species are found with galenite in a vein known as the "Lucky Boy mine," in Butterfield Cañon, which is in the Oquirrh Range on the west side of Jordan Valley, Utah.

5. *Priceite.*—This borate of lime, which I received from Mr. Thomas Price, in San Francisco, in March, 1872, has been noticed by Mr. Chase, and its mode of occurrence and probable origin described by him in this Journal (III, v, 287), accom-

* I have observed it in minute prismatic crystals in the well-known chrysoberyl locality at Haddam, Conn.

panied by two analyses. A recent examination of this mineral —of the soft chalky variety—affords the following results. Its specific gravity is 2·262 to 2·298. It resembles chalk, but is even softer than that mineral. Its powder under a half inch magnifying power is seen to consist exclusively of minute rhombic crystals. It is insoluble in water which removes only a very minute quantity of common salt, not a constituent of the mineral. It dissolves completely in dilute hydrochloric acid, and this solution promptly deposits abundant crystals of boric acid. Its filtrate is completely free of sulphates, and reacts only for lime, with a trace of iron and alumina. In the close tube it evolves abundant neutral water, and at a red heat fuses to a white enamel. The spectroscope discloses from its solution in hydrochloric acid only the double spectrum of boric acid, with the lines of calcium and sodium. It contains no carbonate of lime, which might very naturally be looked for. Five grams of the air-dried mineral afforded me by the volumetric method only 0·7 c.c. of CO_2, equivalent to $\frac{1}{2\,5\,0\,0}$ of calcium carbonate in the weight taken—hardly a trace.

Its water of constitution is very constant—and it is almost non-hygroscopic. Two determinations of the water in the air-dried mineral gave 18·395 and 18·40 per cent of water, while two of the same dried at 212° gave each 18·29 per cent.

Dried at 212°, three analyses made by hydrofluoric acid—which leaves the boric acid to be determined by the loss—gave as follows:

	1.	2.	3.	Mean.	Oxygen ratio.
Water	18·29	18·29	18·29	18·29	1·8
Lime,	32·38	31·37	31·73	31·83	1
Na Cl. Fe Al	·93	1·00	·97	·96	
Boric acid	48·50	49·34	50·01	49·00	3·7

The oxygen ratio gives approximately 4Ḃ, 3Ċa, 6Ḣ; the lime is a little too high. The probable formula of the mineral is $\dot{C}a^3\dot{B}^4\dot{H}^6$, which makes the mineral to differ from hydroboracite by containing one-third less water and no magnesia. This formula requires: water 19·43, lime 30·21, boric acid 50·36 =100.

This mineral is certainly different from the cryptomorphite of How, to which it has been provisionally referred by Price and others. It has the microscopic crystallization described by Dr. Robb as belonging to the Nova Scotia species; but the absence of soda and the greater ratio of the protoxide base carries it much nearer to hydroboracite, from which it is separated by containing no magnesia and less water. It is certainly not a mechanical mixture, as its finely divided condition might seem to indicate. The microscope completely sustains the constant results of analysis on this point. As it appears therefore to be

a new species, I would propose for it the name *priceite*, in honor of Mr. Thomas Price, the well known metallurgist of San Francisco. Mammillary and radiate masses of aragonite, some of great size, but more frequently as crusts, occur with the priceite, and were at first mistaken by the miners for a variety of this borate of lime.

6. *Ulexite.*—The boronatrocalcite of Ulex proves to be an abundant mineral in Nevada and Arizona. The specimens of this species which I have examined are from near Columbus, Esmaralda County, Nevada, where it occurs in beds of considerable extent, mixed with sulphate of soda and gypsum. It is found in round masses, as large as the fist and larger, which when broken show the fine fibers of silky luster not to be distinguished from the *tiza* of Peru. This species, it is said, occurs abundantly in the Arizona desert, and also near Wadsworth, Nevada, much mingled with dirt.

Near Columbus, Nevada, they have likewise found large quantities of borax diffused in the soil, and Prof. Price informs me (June 6, 1873), "that all the borax produced there is obtained by lixiviating the soil and crystallizing out the borax in the usual way. I have been informed by trustworthy parties that they can manufacture at least forty tons of commercial borax every day; the difficulty is to find a market for so much."

About twenty miles west of San Bernardino, California, is the so-called "Cane Spring District," where ulexite is found over an area, said to be about ten miles in width by fifteen in length. The surface of the ground is covered with efflorescent salts, commonly known as "alkali," beneath which the borax salts (chiefly *ulexite*) are found, at a depth of a few inches, when they exist at all. As these "alkaline" wastes are now attracting attention from the commercial importance attached to the borax salts, we may hope to obtain yet other contributions of interesting species. The saline salts removed in obtaining the borax salts recur again after an interval of time, during which the process of solar evaporation in a rainless region brings up by capillary action from a lower stratum fresh portions of the saline solutions. It is a fact long familiarly known to travelers in these desolate regions, that while the lagoons, where any exist, contain only water too strongly saline to be drank, that wells sunk to a moderate depth in the saline soil afford water which can be used. This water is only a more dilute solution of the same salts, which on reaching the surface by capillarity, form the peculiar "alkali" incrustations of the desert.

7. *Borax.*—On the eastern slope of the Sierra Nevada, not far from Walker's pass, borax is found in what appears to be the bed of an ancient lake, large crystals of tinkal having been found in the hardened mud, like the well known crystals of borax found in the mud of Clear Lake in California. But by

far the largest quantity of the borax exists mixed with other salts, incorporated in a sort of indurated mud from which it is extracted by lixiviation.

I have examined several samples of this material which Prof. Price has kindly sent me. One of them, by his assay, contains about half its weight of borax. It is a light gray clay-like looking body, with a strongly saline and alkaline taste, effervesces with dilute hydrochloric acid, and tinges the flame of alcohol green. They are all alike in reacting alkaline, and for sodium, boracic acid, chlorine and sulphuric acid. The portion insoluble in water is attacked by dilute hydrochloric acid with effervescence, and contains alumina, lime, a little ferric oxide and magnesia. Minute crystals of gypsum exist in some of them, but no gaylussite, glauberite or boracite could be detected. Similar deposits containing borax exist in Panamit and Death's Valley in Lower Nevada, which desolate districts have yet to receive a careful scientific examination, for which, in Professor Price's opinion, they offer an interesting but certainly not very inviting field. There are few parts of the earth's surface where human life and endurance are more severely taxed.

8. *Chrysocolla.*—This species, in specimens of unusual size and beauty, is found in a vein, or heavy deposit, of thirty to forty feet in thickness, in the railroad mining district, Elko county, Nevada. Above one hundred tons of it were sent last year to the Revere Copper Company, where it yielded 28½ per cent of copper.

9. *Compact Anglesite.*—This variety of anglesite occurs in large quantity at the Union mines near Cerro Gordo, Inyo county, California, in an Alpine region about twenty miles east of the Sierra Nevada mountains, and at an elevation of more than 8,000 feet above tide. The mineral vein, or ore deposit, occurs in limestone and makes its appearance on the west slope of the mountain (which rises some thousand feet or more higher than the vein). It was indicated at surface by a few boulders or isolated masses of galena, which on exploration ran into a nearly continuous mass of galena mixed with a reddish-brown sand colored by sesquioxide of iron, but without quartz or epigene species derived from lead. Singularly enough, the carbonates of lead occur *below* the anglesite, mixed with the latter species and with galena. At the depth of 600 feet from surface, the ore course is about fifty feet wide, the entire absence of water at that depth and above being a noticeable fact, in considering the paragenesis of species. Water is brought by mules and Indians from a distance of some miles, to supply the hoisting machinery and other needs of the mine, at a cost of 10c. per gallon, and is economized by a careful condensation.

This anglesite often includes unchanged galena. It is of a gray to grayish-yellow color, sometimes dark, or with seams of

yellow covered with druses of small crystals of anglesite, which are quite colorless, brilliant and transparent. The masses are banded like agates. Its density is 6·08, and its pyrognostic characters are those of anglesite. It contains on an average of mining samples about 55 ozs. of silver to the ton of 2,000 lbs., which is materially less silver than is found in the unchanged galena. The "bullion" (silver lead) of this mine as sent to market contains about 120 ounces of silver to the net ton. My informant for these economical facts is Mr. F. F. Thomas, a graduate in Arts and Science at Yale, who is in charge of the smelting works at these mines.*

10. *Platinum and Iridosmine.*—Since the publication (this Jour., v, 384) of my note on the crystalline sands of the Cherokee gold washings in Butte county, California, I have obtained, through the kindness of Mr. G. A. Treadwell, who at my suggestion gave the proper directions, samples of the heavy sands which accompanied the "clean up" of the gold to the last stage of concentration before going into the melting pot. These heavy sands I find to be largely composed of scales of platinum mixed with yet more abundant iridosmine. When the adhering mercury and other foreign matters which disguise the true character of the platinum residues are removed by a slight washing in acid, the beauty of these species is seen, and it is quite easy to select each by the aid of a glass. A few minute zircons and brilliant microscopic crystals of chromite (?) were selected from the sample of about 25 grams which I received. The search for laurite and the anomalous mineral believed by Dr. Genth to be new (this Jour. II, 246), which he described as occurring among sands from California, in 1853, was not successful.

Mr. Glass, the resident manager, informs me that the platinum and its associate minerals are quite abundant at Cherokee, but as the quicksilver does not amalgamate them they have no means of escape from the mechanical force of the stream which washes away much the larger part, thus entailing a loss which there is no means now known to prevent.

Platinum and iridosmine were very early observed in California by Blake and others, among especially the sands of the surface placers near the sea, on the northern coast and in Oregon. But I believe this is the first notice of their being found in the older deep placers now so extensively worked by the hydraulic process.

The "Black Sands" of the Cherokee deep placer washings I find to be composed chiefly of *chromites.* The magnet selects quite sparingly a few crystals and masses of *magnetite*, some of them being also strongly magnetic. An occasional mass of

* The compact anglesite from Arizona, described by Prof. Brush in this Journal, (III, v, 421) is not distinguishable from the Cerro Gordo mineral.

brown iron (*limonite*) occurs, giving off water in the tube, becoming magnetic by heat, and reacting only for iron. The search for *ilmenite* resulted in finding only chromite, with its well-marked reactions. It is highly improbable but that ilmenite exists, but I have not yet after some time and much pains succeeded in finding it. The mass of sands searched by an exploring-glass, discloses some other species besides the abounding zircons, among which the most conspicuous is *rutile* in minute prisms of a fine red color, transparent, sometimes doubly terminated, but rarely compounded; 68 of these little crystals of rutile weighed only 58 milligrams; garnets, epidote, and a few minute fragments undetermined are sparcely found. We may therefore enumerate the mineralogy of the Cherokee washings, so far as known, as yielding gold, platinum, iridosmine, diamond, zircon, topaz, quartz in several varieties, chromite, magnetite, limonite, rutile, pyrite, almadine garnet, epidote. A further search on larger samples of the sands will undoubtedly reveal yet other species. The matrix which has furnished most of the species enumerated (the gold and platinum metals probably excepted), is probably syenite, boulders of which are among the frequently recurring factors of the gravel mass.

11. *Diamonds in California.*—About twenty well-formed crystals of diamond have been picked out of the "sluices" in the deep placer workings at Cherokee, Butte County, since the attention of the miners has been called to the existence of this gem in such situations. One of these diamonds which I have examined weighs about 2¼ carats, and is of a faint yellowish color, with curved faces, and the form of fig. 58, in Dana's Mineralogy. Some of these stones were of a pure water, and have been cut and set as gems.

12. *Sands of the Arizona Desert.*—The search for "diamonds," "rubies," and "emeralds" in 1872, led to the sending of several expeditions into Arizona and southern Nevada. I have had, by the kindness of Mr. Geo. A. Treadwell, an opportunity of examining a portion of the findings of one of these parties, which explored a region about eighty-five miles northwest of Fort Defiance in Arizona. The region is described as one of porphyritic and other eruptive rocks. The "rubies" are garnets, some of very fine color and good size, but whether pyrope or common garnet, an analysis only can determine. Some of them, cut in San Francisco, which I have seen, compare well in color and beauty with the Bohemian stones. The "emeralds" are chrysolite, too faint in color to be used as gems. The "diamonds" are quartz, some opaline, others hyaline, and all smoothly polished. In addition, I find the alalite variety of pyroxene, fluorite (white), magnetite, ilmenite, oligoclase and jasper.

ART. XVII.—*Remarks on the Distribution of the Fossils in the Lower Potsdam Rocks at Troy, N. Y., with descriptions of a few new species;* by S. W. FORD.

WHEN, in the summer of 1871, I published a brief notice of my investigations among the ancient rocks overlooking the Hudson River upon the east in the vicinity of Troy,* I hoped to be able to present shortly thereafter a more detailed account of these rocks, and of their intimate stratigraphical arrangement. Several circumstances have, however, prevented the carrying out of my intended labors in this direction with any degree of satisfaction to myself, and I shall therefore leave the further consideration of this subject to a future occasion. In the present paper I shall confine myself mainly to a few observations relating to the distribution of the fossils in these rocks; and to the description of the remainder of the new species which they have afforded, in so far as these are sufficiently well preserved to admit of being characterized.

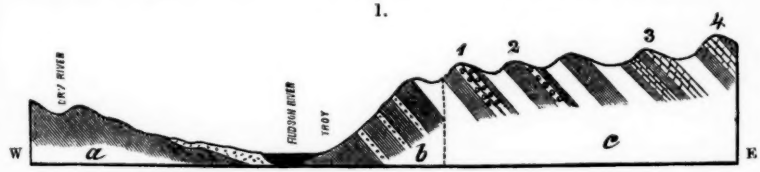
The only rocks of the Lower Potsdam at Troy that have thus far proved fossiliferous are certain thin limestone masses, associated with the great body of coarse slates of which the formation at this place is principally composed. These masses are four in number, or at least occur in four distinct north and south ledges. They all occur within a tract not to exceed half a mile from west to east and considerably less than a quarter of a mile from north to south. Within this tract there are several other ledges, some of them holding thin deposits of limestone; but in these I have not as yet succeeded in finding any fossils. The following is a section across the Hudson River at Troy, not drawn to scale, but designed simply to show the general arrangement of the rocks in this vicinity.

At the point of the section indicated by the vertical dotted line a great dislocation most probably occurs, bringing up the more ancient strata *c* and causing them to overlap or stand above the newer *b*. This would, however, hardly be suspected from the physical structure of the region; since, so far as I have been able to ascertain, the rocks throughout the entire length of the section have the same average (easterly) inclination. I have nowhere observed the precise line of contact between the rocks of *b* and *c*, unless it be in a high ridge about a mile and a half north of this city, where the hard dark-colored slates and thin gray sandstones of the Lower Potsdam appear to overlap conformably the newer shales. At Troy there is a considerable space between them covered with drift.

* "Notes on the Primordial Rocks in the vicinity of Troy, N. Y." This Journal for July, 1871.

The limestones of *c*, which I have for convenience sake designated simply as limestones 1, 2, 3 and 4, are those already re-

1.



a. Shales of the Hudson River formation holding *Trinucleus concentricus*, *Leptæna sericea*, and graptolites. The above species occur at Dry River, opposite Troy.
b. Black shales with thin layers of sandstone, holding graptolites, most probably of either the Hudson River or Utica formations.
c. Slates, sandstones, limestones and limestone conglomerates of the Lower Potsdam group.
1–2. Conglomerate limestone interstratified with coarse slates.
3–4. Even-bedded limestone similarly situated.

ferred to as being the only portions of the Lower Potsdam at Troy that have proved fossiliferous. The annexed table presents a list of the species obtained from them so far as described; and shows also the manner of their distribution among them.

Table showing the distribution of the fossils in the Lower Potsdam group at Troy, N. Y.

	Limestones,	1	2	3	4
1.	Archæocyathellus Rensselaericus*	--	*	?	--
2.	Obolella desquamata	*	*	*	*
3.	" crassa	--	*	*	--
4.	" cælata	--	*	*	*
5.	" nitida	--	*	*	*
6.	Stenotheca rugosa	*	*	*	*
7.	Scenella retusa	*	*	*	--
8.	Hyolithellus micans	*	*	*	*
9.	Hyolithes Americanus	--	*	*	*
10.	" impar	--	*	*	*
11.	" Emmonsi	--	*	*	*
12.	Leperditia Troyensis	--	--	*	--
13.	Microdiscus speciosus	--	*	*	*
14.	" lobatus†	--	*	*	*
15.	Conocephalites trilineatus	--	*	*	*
16.	Olenellus asaphoides	--	*	*	*
17.	Agnostus nobilis	--	--	--	*
18.	Bivalve of undetermined relations	*	*	*	*

It will be seen from the above table that out of the eighteen species enumerated, thirteen are common to limestones 3 and 4;

* This species was described in the March No. of this Journal for the present year, and referred by me provisionally to the genus *Archæocyathus*, Billings. I now consider it entirely distinct from that genus, and have adopted here the generic name at that time proposed for it in the event of its proving to be an independent form. The characters of *Archæocyathellus* are those of this species.

† This species equals the *Agnostus lobatus* of Hall (Pal. N. Y., vol. i, p. 258, pl. lxvii, figs. 5 a–f), and appears to me to belong to *Microdiscus* rather than to *Agnostus*. It occurs in great numbers in the limestones at Troy, but I have never seen a specimen of it showing all the parts in connection.

thirteen to Nos. 2, 3 and 4; fifteen to Nos. 2 and 3; while five are found in all four. No. 1 does not present as good facilities for examination as the others, and has yielded but five species; but when further studied it will, I have no doubt, furnish a larger number. Enough evidence has, however, I think, been obtained and here presented to prove that the limestones in question, with their associated beds, all belong to a single great series of strata. That some repetitions occur in this series I have but little question; but I have been unable, thus far, to identify with certainty the rocks of any of the exposures examined with those of other exposures situated either to the east or the west of them. The thickness of this series remains still undecided. I do not conceive that limestone No. 4 forms the eastern limit of this series: on the contrary, there is much to lead me to suspect that the formation has a rather wide spread beyond; but as the beds to the east of this band that I have examined have, up to this time, proved barren of fossils, I have made the section to terminate with it.

This series I consider for the present to occupy a lower geological horizon than the typical Potsdam sandstone of the New York survey; and to be of nearly if not exactly the same age with the *Olenellus* or Georgia slates of Vermont, and the *Olenellus* limestones on the north shore of the Straits of Belle Isle, determined by Mr. Billings. It may yet prove to be a trifle more ancient or more recent than the above named strata, but there can, I believe, at any rate be no great difference between them in this respect. The fauna of this series is wholly distinct specifically from that of the Upper Potsdam of Wisconsin and the true Potsdam of New York, as well as from that of the more ancient St. John's or Menevian group of New Brunswick and its equivalent in the Primordial of Newfoundland; although connected generically with each of them and strongly so with both that of the Upper Potsdam and Menevian. It will be observed that in this fauna the genus *Microdiscus* is represented by two species. This genus is new to the fauna of the Lower Potsdam, but it will probably yet be found to range throughout the Primordial, since it is known from both the Longmynd and Menevian groups of Wales, the St. John's group of New Brunswick, the Lower Potsdam as above stated, and may possibly be present in the Upper Potsdam of Wisconsin, in the shape of certain minute pygidia referred by Prof. Hall with doubt to *Agnostus* (16th Reg. Rep. 1863, p. 180). It occurs also, as is well known, in Augusta county, Virginia, where it is associated, according to Dr. Emmons, with graptolites. The genus *Archæocyathellus* is, so far as known, peculiar to the fauna of the Troy limestones.

On the south shore of the St. Lawrence, in Canada, there occurs a great series of strata referred by the Geological Survey

of Canada to the Potsdam group, the conglomerates of which have afforded several of the species found in the Lower Potsdam at Troy, as well as several occurring in the Lower Potsdam of Vermont and Labrador, with many others. The exact age of the formation holding these conglomerates is not yet positively settled; but it is, by Mr. Billings, regarded as at least not far from that of the Potsdam.

The fauna of the Troy limestones appears to me to supply in part a long-recognized blank in the Paleontology of our State. The Primordial fauna with us has hitherto been a meager one, being confined, with the exception of *Scolithus*, to the few species found in the Potsdam sandstone at Keeseville, Essex County. In the Troy limestones we now have, however, quite an extensive and strongly-marked fauna, establishing many important relations between these rocks and the Primordial of other regions and other horizons, both at home and abroad. This fauna is probably yet far from complete; and should these rocks be further investigated, I have no doubt that many additions will be made to it in the future. My own opportunities for study in this field have been very far from what I could have desired; and have prevented me from giving to it that connected and systematic investigation of which I believe it eminently deserving.

Descriptions of new species of Fossils from the Lower Potsdam group at Troy, N. Y.

Microdiscus speciosus, sp. nov.

Description.—Head destitute of eyes and sutures, semi-elliptical, with a conspicuous border all around, thickened at the edge, which in the majority of cases carries from 5 to 6 minute tubercles on each side; border expanded in front. Glabella long, conical, prominent, smooth, without neck furrow, extending in an obscurely triangular projection slightly beyond the posterior outline, separated from the cheeks by rather wide and deep dorsal furrows, sometimes, though only in very rare instances, obscurely lobed by from three to four faint furrows on each side. Cheeks convex, prominent, well defined by the dorsal and marginal furrows. Posterior angles narrowly rounded.

Fig. 2. *Microdiscus speciosus*. *a*. Head; *b*. Pygidium. Natural size. The parts figured belong to two different individuals.

Thorax with four equal segments. Pleuræ pointed, straight except at their extremities, which are bent down and slightly recurved, deeply grooved for nearly their whole length. The rings of the axis have a slight groove across them in the posterior half of each. The fourth or hindmost ring appears to be anchylosed

to the pygidium, at least it invariably accompanies it when the latter is found isolated.

Pygidium as long as the head and of nearly the same shape, but slightly narrower, taking the extreme measurements, and more rapidly tapering; gracefully curved in outline. Marginal rim distinct all around, widest anteriorly, distinctly raised or thickened at the edge. Axis conical, sometimes acutely so, long and slender, extending very nearly to the margin, divided by faint cross furrows directed slightly backward into eleven rings or segments. Side-lobes highly convex and without furrows. The axis and side-lobes appear to overhang the marginal rim at the posterior extremity, giving the border the appearance of being only about half as wide behind as it is in front.

The entire surface is finely punctate. In one specimen of the pygidium, out of a large number of perfect specimens examined, there appears to be a twelfth ring in the axis.

Length of a specimen of the usual size with all the parts in place, but too imperfectly preserved to be figured, half an inch. Length of thorax 0·13 of an inch. I have seen but a single specimen showing conclusively the true number of thoracic segments. This species had the habit of rolling itself up into a ball, and is quite often found in this state. In the specimen just noticed, the pygidium is bent slightly under the body. Nearly all of the specimens that I have seen, that were in a perfect condition before extraction, exhibit this tendency to coil themselves up, which appears to account for the thorax breaking away in most cases.

This pretty little trilobite occurs in both even-bedded and conglomerate limestones of the Lower Potsdam at Troy; also at Bic Harbor, Canada, where it has been collected by Mr. T. C. Weston of the Geological Survey of Canada. The Troy specimens were collected by the writer. It is a rather common fossil at Troy, the head and pygidium usually occurring detached from the thorax. The head sometimes attains a length of 0·38 of an inch, but this is quite unusual.

This species closely resembles *Microdiscus punctatus* (Salter), from the Menevian group of Wales:* but it differs from that species in not possessing a neck spine, in the greater number of its caudal rings, and in having the marginal rim of the head tuberculated. The head, compared with that of *Microdiscus Dawsoni* from the St. John's group of New Brunswick (Acadian Geology, Dawson, 1868, p. 654), is proportionally longer, and is wanting in the grooves of the border of that species.

Leperditia Troyensis,† sp. nov.

The following description is based upon a single right valve, the only specimen of this species that I have seen.

* Quart. Jour. Geol. Soc., Aug., 1864, p. 237.

† Figures of this and the following species will be given hereafter.

Description.—Minute, obscurely pentagonal in outline, greatly narrowed in front, broad behind, narrowed at either extremity, posterior one somewhat obtusely angular. Dorsal margin straight, ventral margin gently rounded. Surface depressed convex, convexity greatest a little behind the mid-length. Eye-tubercle prominent. Marginal rim well-defined all around except at the hinge. A distinct marginal groove can be traced entirely around the carapace, but it is very faint in the upper portion. It is most distinct along the forward half of the ventral outline. Surface smooth and polished.

Length 0·18 of an inch; breadth 0·12. Occurs in even-bedded limestone of the Lower Potsdam at Troy. Collected by the writer.

The characters of this species agree very closely with those of *Leperditia Solvensis* Jones,* from the Menevian group of Wales: but our species is larger, a little different in shape, and provided with a distinct eye-tubercle. They appear, however, to be very nearly related.

In the limestones at Troy there occur certain small lamellibranchiate-like shells whose affinities I shall leave for the present an open question. They are very abundant, and are represented up to this time by a single species. Externally they present something of the appearance of a small *Modiolopsis*. As no undoubted lamellibranchiates have, however, been hitherto detected in strata certainly more ancient than the Calciferous Sandrock, it is quite possible that, when they come to be better understood, they will be found to belong to some as yet imperfectly known group of crustaceans. While I am unable to decide to what class they belong (although inclining to the belief that they are lamellibranchiates), I consider some notice of them needful here and shall describe them as fully as the material will allow, without for the present giving them a distinct name. The following is the description:

Bivalve of uncertain class, gen. nov.?

Description.—Shell transversely oblong or suboval in outline, convex, widest posteriorly, narrowed at either extremity, with an oblique posterior ridge, and small depressed umbones situated anteriorly, sometimes presenting an obscurely bi-lobed appearance in front. Dorsal margin nearly straight, ventral margin uniformly rounded. In the interior of the left valve, as shown by a gutta-percha cast of an impression in stone of this valve, there is a wide and deep furrow with a slightly raised line along the middle of it corresponding to the oblique ridge on the outside; and a distinctly impressed line passing

* Annals and Magazine of Natural History, 2d series, vol. xvii, Feb., 1856, p. 95.

from the lower anterior into the upper posterior portion of the valve following the curved ventral edge, from which it is separated by a broad flattened border. This line is deeply sunken anteriorly, becomes almost obsolete or discontinuous in passing the oblique internal furrow, beyond which, in the posterior portion of the shell, it is less distinct, though clearly shown. Just in front of and above the anterior limit of this line there is a slight conical protuberance. Further than this nothing can be made out, owing to the imperfection of the material. The shell is thick, with the surface finely striated concentrically.

I have never observed a specimen of this singular little shell with the two valves together, but they are frequently found side by side in the same hand-specimen of stone.

Length rarely more than 0·16 of an inch; usual width about 0·10. Occurs in both even-bedded and conglomerate limestone of the Lower Potsdam at Troy. Collected by the writer.

Besides the foregoing species I have from the Troy limestones several specimens of an *Orthis*, but too imperfect to describe; and also a few specimens of what seems to be an undescribed *Lingulella*, which cannot at present be dealt with for the same reason.

Troy, N. Y., May 14th, 1873.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On a new Determination of the Earth's Density.*—Cornu and Baille have redetermined the density of the earth by means of the torsion-balance, first employed for this purpose by Cavendish in 1798. Their researches commenced with a complete study of the torsion-balance, as an instrument for absolute measurements. Profiting by the information thus acquired, they constructed the apparatus with which to obtain the constant of attraction—and hence the earth's density,—in a cellar room of the École Polytechnique. The lever of the torsion-balance consisted of a small aluminum tube 50 centimeters long, carrying at each extremity a copper ball weighing 109 grams. At its center was a small mirror, which reflected to the reading telescope the image of a scale placed 5·6 meters distant. The filament of suspension was an annealed silver wire, 4·15 meters long. It was put in position in September, 1871. At the time of the experiment, the balance made a double oscillation in 6m. 38s. The attracting mass was mercury contained in two hollow cast-iron spheres 12 centimeters in diameter, so connected that all the mercury could be forced into either or be divided between them. As improvements over the apparatuses used by Cavendish, Reich, or Bailly, the authors

note: 1st, the reduction of the size of the apparatus to one fourth, which is an advantage, since—the time of oscillation being the same—the deviation is independent of the weight of the suspended balls and inversely as the homologous dimensions; 2d, the use of mercury instead of lead; 3d, the elimination of electric perturbations by good ground connections; and 4th, the electric registering apparatus, which gives graphically the number of oscillations, the time of each, and the minor attending circumstances. Two series of observations, comprised in twenty groups, and including more than two hundred complete oscillations, were made with this apparatus, one being in the summer months of July and August, the other in the fall and winter months of 1872–73. The summer series gave for the mean density of the earth 5·56; the winter series 5·50. The mean variation was 1·25 per cent for the summer, and 1·5 per cent for the winter series. The difference in the results is due to a slight flexure of the lever; the authors regard, therefore, the first above given as the more accurate. Moreover, the value obtained decreases according to an almost regular law, as the attracted masses increase: varying from 6·02 when the lever was used alone, to 5·60 when the mass upon it was heaviest. This source of error is eliminated when the mass of the lever is inappreciable in relation to that of the balls. Calculating the limiting value by applying an empirical formula representing this law of variation, the mean density of 5·55 is obtained. The authors take 5·56—the mean of the summer determinations given above,—as accurate to within one per cent.—*Compt. Rend.*, lxxvi, 954, April, 1873. G. F. B.

2. *On Spectral Lines of Low Temperature.*—The Marquis of Salisbury has observed that there appears in the tube of a thermometer whose bulb rests on an insulated metallic plate connected with one of the secondary poles of a powerful induction coil, the other pole being unconnected, a greenish light in the vacuum above the mercury, produced, as it would seem, by induction. The point of special interest, however, is the fact that no perceptible heat attends this light, uninterrupted action even for five minutes producing a rise in the mercurial column of only three-fourths of a degree; and even this, the author thinks, may not be due to heat. This light then, appears at a temperature below 60° F. It is strong enough for spectroscopic examination, and affords a spectrum differing in different thermometers. Instruments of the best makers, like Casella and Elliott, gave only three lines which were identified as mercury lines. A feeble fourth mercury line appeared once. In thermometers of makers of less repute, four additional lines appear, which, by comparison, were ascertained to be carbon lines. They are due, evidently, to a want of cleanliness in preparing the instrument, the surface of glass seeming to attract readily thin films of grease. In a very dirty thermometer, one or two additional lines appeared in the green. These results are interesting since they show that carbon vapor becomes luminous under electric influence at a lower temperature

than hydrogen. If, for example, a Geissler tube containing a hydrocarbon be arranged as described above, and the free pole be applied to the upper end, the full discharge passes, and the hydrogen F and the carbon lines *f f* appear. But on withdrawing the free wire, F disappears while the carbon lines remain, nearly as bright as before. As, therefore, the carbon lines are visible when the hydrogen lines have not yet appeared; so the carbon lines have begun to expand while the hydrogen lines still remain sharp, and may reach the condition of a continuous spectrum much sooner. The author suggests that by admixture of other elements with the mercury of a thermometer, the lowest temperature of their luminosity may be determined.—*Phil. Mag.*, IV, xlv, 241, April, 1873. G. F. B.

3. *On the Solvent power of liquid Carbon Dioxide.*—By means of an ingenious apparatus, consisting essentially of a hydrostatic press, by which mercury may be forced—if necessary, under a pressure of 900 atmospheres—into a cylindrical reservoir of glass terminating in a narrower thick tube, CAILLETET has succeeded in liquefying carbon dioxide gas under conditions which enable him to test its properties. Liquid carbon dioxide is colorless, mobile, and a non-conductor of electricity. A powerful induction-spark appears white and dazzling in the liquid, but does not decompose it. Attempts to determine its coefficient of compressibility gave no uniform results. Sodium chloride, sodium sulphate, calcium chloride, calcium carbonate, sulphur, phosphorus, stearin, and paraffin, are insoluble in carbon dioxide. Iodine is sparingly soluble, with the color given by carbon disulphide. Potassium carbonate becomes dicarbonate (?) insoluble in an excess of the liquid. Water dissolves it only slightly, petroleum 5 or 6 times its bulk. It is only slightly dissolved by carbon disulphide, but is miscible with ether in all proportions. It dissolves liquid, but not solid fats, and is not reduced by sodium.—*Compt. Rend.*, lxxv, 1271, Dec., 1872. *Bull. Soc. Ch.*, II, xix, 20, Jan., 1873. G. F. B.

4. *On the Density of the Vapor of Phosphoric Chloride.*—Two theories of equivalence are in use; one of these assumes it to be variable, the other invariable. Phosphoric chloride has been appealed to by both parties in proof of the accuracy of their positions; the one claiming that in PCl_5 the phosphorus was a pentad, while in PCl_3 it was a triad; the other that phosphorus was always a triad as in PCl_3, and contending that PCl_5 was a *molecular* combination of PCl_3 with Cl_2, as was proved by the density of its vapor. WURTZ, as the champion of the former view, having ascribed its anomalous vapor-density to dissociation, has redetermined this density, taking care to reduce the dissociation to a minimum. He first used the methods of Wanklyn and Playfair, and volatilized the chlorides in a balloon containing air, immersed in a bath of paraffin, at temperatures from 129° to 145°, and under a pressure of vapor of 148 to 391 mm. The results gave a density for the vapor of 6·118 to 6·7; mean 6·5. The calculated density for two volumes is 7·217. In his second series of experi-

ments, Wurtz sought to avoid the dissociation by diffusing the vapor of the phosphoric chloride in a space filled with one of the products of this dissociation, phosphorus chloride. In this way, a series of twelve experiments was made, at temperatures from 160° to 175°. The results are as follows, the number of the experiment being given in the first line, the density obtained in the second, and in the third the tension of the vapor in millimeters of mercury:

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
7·25	7·38	7·74	7·06	7·03	8·30	6·88	7·16	7·44	6·80	7·00	6·68
194	338	168	271	343	174	411	394	214	413	318	423

The mean of these results is 7·226; a number according well with the calculated density, 7·217. Hence when dissociation is prevented, phosphorus chloride is normal in vapor density, the compound PCl_5 is an atomic combination, in which each chlorine atom has an equal value, and the equivalence of phosphorus is variable.—*Compt. Rend.*, lxxvi, 601, March, 1873. *Bull. Soc. Ch.*, II, xix, 451, May, 1873. G. F. B.

5. *On Ethyl-amyl.*—This hydrocarbon was discovered by Wurtz in 1855 and has since been investigated by Schorlemmer, who obtained from it the chloride, acetate, alcohol, and corresponding acid. This latter chemist having proved that each of the normal paraffins, on treatment with chlorine, gives both a primary and a secondary chloride, it appeared of interest to test this question in the case of paraffins not normal in constitution. Grimshaw, under his direction, has investigated ethyl-amyl, which, since it is obtained from amyl alcohol, has the constitution

$$\left.\begin{matrix}CH_3\\CH_3\end{matrix}\right\}CH\text{-}\text{-}CH_2\text{-}\text{-}\text{-}CH_2\text{-}\text{-}\text{-}CH_2\text{-}\text{-}\text{-}CH_3.$$

It was prepared by the action of sodium upon a mixture of ethyl and amyl bromides, the former being in excess. From 150 grams of each, 100 grams of product were obtained, 80 grams of which were ethyl-amyl and 20 grams diamyl. After purification, the former boiled constantly at 90° and had a specific gravity of 18·4° of 0·6833. On chlorination, a product boiling from 140° to 150° was obtained; this was converted into the acetate, which boiled from 160° to 175°; and yielded, on treatment with potassium hydrate, a mixture of two alcohols, one boiling at 146°–148°, the other at 163°–165°. These were oxidized together, and afforded (1) iso-œnanthylic acid, boiling at 210°–213°; and (2) methyl-amyl-ketone, boiling at 143°–145°. Hence the primary alcohol above mentioned is isoheptyl alcohol, and the secondary alcohol is methyl-amyl-carbinol. From these results it appears that ethyl-amyl or dimethyl-butyl-methane, is acted upon by chlorine in the same way as the normal paraffins.—*J. Chem. Soc.*, II, xi, 309, April, 1873. G. F. B.

6. *On a New Synthesis of Aromatic Acids.*—Since the alkali-alcohols, when acted upon by carbon dioxide, yield fatty acids, the phenols thus treated may be expected to give homologues of salicylic acid. So the acetylene series of hydrocarbons, yielding,

as they do, metallic derivatives easily, should, by this treatment, also afford a series of acids. PATERNÒ, therefore, passed a current of dry carbon dioxide gas through acetenyl-benzol, containing fragments of sodium. By suitable methods the product was purified and found to be phenyl-propiolic acid, $C_6H_5.C{\equiv}C.COOH$. He is still investigating this subject.—*Gaz. Chim. Ital.*, ii, 553, Feb., 1873. G. F. B.

II. GEOLOGY AND NATURAL HISTORY.

1. *On Glacial Movements in Northern New York;* by R. P. STEVENS. (Editorial correspondence, dated New York, June 17, 1873.)—I have just come back from a trip into the mountains west of Westport, Lake Champlain, returning via Whitehall through the northwest corner of Saratoga Co. On my trip, I kept constantly in mind the subject of glacial movements, and made many observations confirmatory of the view, that the courses in the valleys corresponded to the direction of these valleys.

1. Along the valley of Lake Champlain, in the lower lying rocks, the general direction of the striæ corresponded to the longer axis of the valley or north and south, though there was a variation of 20°.

2. On the higher hills and mountains the striæ are more from the northwest to southeast. This is very apparent at Split Rock Mt., just north of Westport, also in the mountains west toward Elizabethtown, and at Mt. Moriah. It is a striking feature of the landscape to see the struck side of mountains and the streaming through the gaps of drift, change as we ascend from the lake.

3. At Luzerne, Warren Co., on the Hudson River, the drift moved down the stream or southward, conforming to the trend of the valley, and forms long and high sandy ridges with or without large boulders. In the town of Corinth, it occurs piled into large hills and filling up an ancient valley.

4. But, in Hadley, Saratoga Co., just opposite the village of Luzerne, the Sacanadaga River flows from the west, the valley opening into the Hudson at almost right angles. The drift flowed down this valley or eastward, even in some bends having a north of east direction.

Ascending Mt. Anthony, which lies in the angle of the two rivers, we find evidence of drift flowing over from the northwest. This is more marked on ascending from the Sacanadaga into the mountains of Day Township. When up to the height of these mountains, we could plainly see that the drift moved over the valley and over the Kayderoseras Mts. south of it. Their heads have been shaved off by ice action, which moved over them from the northwest.

It was to me very interesting to find such confirmation of the view set forth by Prof. Dana. I thought I could see just where the change of course took place as we ascended the hills, and I hardly doubt, that if I had been on foot and had my aneroid

with me, I could have marked the exact elevation above the valleys, and observations made at widely separated localities would have confirmed each other.

In the valley of Champlain, I found seven distinct terraces from the water level up to 750 feet. I found *Tellina Groenlandica* in No. 1 and No. 4, the latter two hundred and fifty feet by estimate above the lake.

2. *Deep-sea chalky deposits but little magnesian.*—The analyses which have been made of the chalky mud that has been brought up from the bottom of the Atlantic, have found but little magnesia. An analysis by J. Hunter obtained (Jour. Chem. Soc., II, viii, 144) 4·00 per cent of carbonate of magnesia to 61·34 of carbonate of lime; and another of J. Mahony (Chem. News, xxi, 91) 1·76 per cent to 58·80 of carbonate of lime. Besides these constituents, Hunter's analysis found 23·36 silica with 5·31 of alumina, 5·91 of sesquioxide of iron, besides the above = 99·92; and Mahony's, 26·60 silica, 3·80 sesquioxide and phosphate of iron, with 4·20 of soluble salts, 2·30 of organic substance, 2·50 water and 0·08 FeO.

An analysis by C. W. Gümbel (Jahrb. Min., 1870, 753) of a specimen stated to have been obtained in 29° 37′ N. lat. and 18° 20′ W. long., at a depth of 2,350 fathoms, and made after separating 10 p. c. of foraminifers and large, organisms, and 1·3 of mineral grains, found 1·26 per cent of lime and magnesia supposed to be in part combined with phosphoric acid, 1·44 carbonate of magnesia, with 59·65 carbonate of lime, 20·90 silica, 3·05 organic substance, and 2·34 water and loss.

3. *Nummulites and Orbitolites in the Mesozoic, Belemnites in the Eocene, and Ammonites in the Carboniferous.*—Gümbel has announced the occurrence of a species of Nummulite, which he names *N. Jurassica*, in the Jurassic beds of Franconia; also two species of Orbitolites, *O. præcursor* Gümb. and *O. circumvallata* Gümb., in the Lias of the vicinity of Roveredo (Jahrb. f. Min., 1872, 241), although till recently this genus was unknown from rocks below the Cretaceous. We now know also of Eocene belemnites—*B. rugifer* Schlœnb.—from the Eocene of Ronca; and lately Mr. Waagen has discovered, in the Carboniferous formation of India, supposed to be of the Carboniferous age, true Ammonites.—*Bibl. Univ.*, May 15, 1873.

4. *Bed of the Rhine at the falls of Schaffhausen changed in the Glacial era.*—Mr. Wurtemberger observes that the falls of the Rhine at Schaffhausen did not exist in the Glacial era. The river at the falls is cut out of the Upper Jurassic limestone, and its right bank is covered with well characterized drift. Along a course cutting off the present bend in the stream, there is no trace of the limestone, and only deposits of pebbles, indicating the site of an old N.N.E. and S.S.W. valley of erosion or river bed, nearly in the direct course of the stream. The glacial deposits evidently filled this ancient valley, and thus forced the river from its course, giving it a bed around south and west to a point where, by a fall

of about eighty feet, it regains again its old channel.—*Jahrb. Min.*, 1871, 582.

5. *Phosphatic character of the shells of Obolus.*—Analyses by A. Kupffer show that the shells of Lower Silurian *Obolus* have nearly the composition of a fluor-apatite. He obtained from a specimen from Jamburg in Ehstlands,

P	C	Fl	Fe	Mg	Ca	ign.	quartz.
36·57	2·42	3·31	4·90	0·62	50·47	2·57	0·53=101·39

from which, deducting the oxygen in excess, on account of the fluorine, 1·59, leaves 99·80.

A concretion of Trilobite shells contained, according to the same chemist, PO_5 19·45, CaO 45·06, CO_2 16·45, Fl 2·88, with a little FeO, MgO, and 6·80 of volatile matters mainly bituminous, corresponding to 42·46 phosphate of lime, 31·81 carbonate, 5·91 fluorid of calcium, with some carbonate of iron, and other impurities.

6. *Statistics of Mines and Mining in the States and Territories west of the Rocky Mountains* (for 1871); by Rossiter W. Raymond, U. S. Commissioner of Mining Statistics. Washington: Government Printing Office, 1872. 566 pp. 8vo.—This volume, so long expected, has been delayed by no fault of the author, whose promptness in the dispatch of his work is well known. It embodies the statistics of 1871, and is known as the Report of 1872, but its publication has been delayed until July, 1873, although copies were distributed to members of Congress in March, 1873. This delay in the issue of a document so important to a large number of persons engaged in industrial and scientific pursuits in a great degree, baffles the object of the Commissioner—which the Commissioner on his part so well and promptly discharges. The contents are divided in three parts, into twenty-one chapters with an introduction and appendix. Part I, Condition of Mining Industry. Part II, Metallurgical Processes. Part III, Miscellaneous. The States and Territories considered are California, Nevada, Oregon, Idaho, Montana, Utah, Arizona, New Mexico, Colorado, and Wyoming. The details of facts respecting each of these regions are full of interest, and are compiled with care from the most authentic sources. The chapter on the treatment of auriferous ores in Colorado is translated, with annotations by the Commissioner from a series of articles by Mr. Albert Reichenecker of Central City, Colorado, printed originally in the German *Berg- und Hütten-Zeitung*, and is illustrated by original drawings of the mill machinery and a full discussion of the results of crushing and amalgamation. The results of Mr. J. D. Hague's investigation on the same subject (*Mining Industry*, vol. iii, King's 40th Parallel Survey) are also given, both as to the mechanical treatment of ores and the results of smelting. A chapter is given on the "Speed of Stamps in Colorado," and another on "The Washoe Pan Amalgamation," abridged from Mr. J. D. Hague's memoir in the volume just named, and, for the chemical part, from the researches of Mr. Arnold Hague in the same volume. The Plattner Chlorination process for the treatment of Auriferous Sulphurets

contain the latest results by Dabken, of Grass Valley, who is the best authority for the American development of this method—and Mr. F. B. Miller's gold refining by chlorine gas, as practiced in Australia, is also given in detail. The smelting of silver ores (chapter xv) completes the list of metallurgical processes. The bullion products of the U. S. have been carefully compiled by Mr. Raymond, and we append from the Mining Journal the amounts produced for the years from 1869 to 1872 inclusive.

	1869.	1870.	1871.	1872.
Arizona	1,000,000	800,000	800,000	625,000
California	22,500,000	25,000,000	20,000,000	19,049,098
Colorado	*4,000,000	3,675,000	4,663,000	4,661,465
Idaho	7,000,000	6,000,000	5,000,000	2,695,870
Montana	9,000,000	9,100,000	8,050,000	6,068,339
Nevada	14,000,000	16,000,000	22,500,000	25,548,801
New Mexico	500,000	500,000	500,000	500,000
Oregon and Washington	3,000,000	3,000,000	2,500,000	2,000,000
Wyoming	------	100,000	100,000	100,000
Utah	------	1,300,000	2,300,000	2,445,284
Other sources	†500,000	525,000	250,000	250,000
Total,	61,500,000	66,000,000	66,663,000	63,943,857

The decline of over two and a half millions in 1872 is attributed to the decline in the workings of shallow placers in California and the Territories; while the permanent works (quartz mines and hydraulic mines) have made increased returns, especially the silver mines of Nevada, which have increased 11½ millions since 1869. The product of 1872 was about equally divided between gold and silver mines, if the bullion of the Comstock lode is reckoned in the latter class. Mr. Raymond says: "The transition from precarious surface mining to organized permanent and extensive work is going steadily forward. Every year witnesses a substantial gain; and though the aggregate production may fluctuate, there is no real retrogression, but a constant advance, in this most important industry."

7. *Royal Mineralogical Museum in Dresden.*—A note by Dr. Geinitz in the Dresden Journal of June 7th, states that the Dresden Museum has been recently enriched by the gift of a specimen of *pterosaur*, recently obtained at Eichstädt, Bavaria, which has the *impression of the wings distinct;* and that in this respect and others it is so much like the specimen that was found at the same place in 1872 and purchased by the Museum of Yale College, that the two might be taken for twins. The spread of the wings is about three feet. The species is closely allied, according to Meyer, to the *Rhamphorhynchus Gemmingi.*

8. *Descriptive and Analytical Botany, by* Le Maout *and* Decaisne; *translated by* Mrs. Hooker, *with additions, appendix, &c., by* J. D. Hooker. pp. 1066, small 4to. 1873. London: Longmans, Green & Co.—The full title of this important work is subjoined,‡ for the advantage of the many who in this country are

* Including Wyoming. † Including Utah.

‡ A General System of Botany, descriptive and analytical, in two parts. Part I, Outlines of Organography, Anatomy, and Physiology; Part II, Descriptions

interested in botany, and who may desire or who ought to procure it. We could not in fewer words explain its nature and scope, the history of its production, and of its reproduction in the present form. It is the *desideratum*, the general work which we are unceasingly asked to indicate by teachers, botanical travelers, scientifically professional men, medical or other, and the amateur botanist, no less than by more serious cultivators of the science, who feel the want of something more than a local manual or flora and a common text-book. Since Lindley's Vegetable Kingdom ran out of print, there has been nothing in the English language to recommend, and perhaps nothing but the French original of this in any other. Lindley's volume was a noble one, in spite of serious faults, and it had the advantage—as yet unapproached—of giving an almost complete account of or references to the medical and economical uses of plants, as well as a list of all the known genera. In the present work, however, we find a judicious selection. Among its many merits, the crowning one, for the devoted botanical student, is in the most copious, excellent, and chiefly new illustrations (in wood-cuts) of the second and far most important part of the work. These give it a value which cannot be over-estimated. Those which are not original are taken from excellent sources, such as the Geneva Am. Bor. Illustrata. The whole are here reproduced from electrotypes taken from the French cuts, so that there is only the difference between the original and the English editions which one ordinarily perceives between the French and the English printing of such illustrations. The first is of much less consequence to us, and might have been abbreviated or revised in some particulars; but the copious illustrations are a great help.

The original work was duly noticed in this Journal. The English reproduction of it has reached us barely in time for the present announcement, which we are unwilling to postpone. Nothing which a critical examination is likely to discover can seriously qualify our judgment (founded on considerable use of the original in French, and a cursory examination of Mrs. Hooker's translation), that this ample volume well supplies a great want in this country; and that the heartiest thanks of all English speaking cultivators of the science are due to the wife of our eminent English botanist, for the spirit with which she has undertaken, and for the successful execution of, her most laborious share in its production. As to Dr. Hooker's part of the work, there is no need to commend it. The wonder is how and when he found time for it.

and Illustrations of the Orders. By EMM. LE MAOUT, M.D., Member of the Philomathique Society of Paris, and J. DECAISNE, Member of the Institute of France, Professor of Cultivation, Jardin des Plantes, Paris. With 5500 figures by L. Steinheil and A. Riocreux. Translated from the original by Mrs. HOOKER. The Orders arranged after the method followed in the Universities and Schools of Great Britain, its Colonies, America, and India; with Additions, and Appendix on the Natural Method, and a Synopsis of the Orders, by J. D. HOOKER, C.B., F.R.S., L.S. and G.S., M.D., D.C.L., Oxon., LL.D., Cantab., Director of the Royal Botanical Gardens, Kew; Correspondent of the Institute of France. London: Longmans, Green & Co. 1873.

We can only here add that, in its English form, the small folio is brought down to the small quarto, or rather to something between quarto and octavo (i. e., the volume is 10×7×2 inches), which will generally be thought an improvement. It is brought out under the cordial coöperation of the original authors, and is published, by the Longmans, for 52½ shillings. A. G.

9. *Fly-catching in Sarracenia.*—In the English edition of Le Maout and Decaisne's System of Botany, noticed above, I find the following note by the editor. There is nothing answering to it in the original French.

"*Sarracenia rubra* has been vaunted in Canada as a specific against small-pox, but has not proved to be such. The pitcher-shaped leaves are effective insect-traps; a sugary excretion exudes at the mouth of the pitcher and attracts the insects, which descend lower in the tube, where they meet with a belt of reflexed hairs, which facilitate their descent into a watery fluid that fills the bottom of the cavity, and at the same time prevents their egress." (p. 214.)

Sarracenia rubra (which does not grow within several hundred miles of Canada) is a slip; *S. purpurea* being meant. But the present object is to call attention to the statement that *Sarracenia* produces a sugary excretion which attracts flies to their ruin, this being the first time, so far as I know, that any such statement has appeared in print. The fact of the excretion in *Sarracenia flava* is certain. My attention was called to it several months ago by Mr. Hill of North Carolina, who had observed it, who rightly described the excretion as appearing on the inner face of the over-arching hood, just above its base, and who insisted—I know not upon what evidence—that it intoxicates or stupifies the insects that sip it, whereupon they tumble into the well beneath. To test this statement, some strong plants were secured by Mr. Canby and myself, during a visit to Wilmington, N. C., in April last. We observed then and since, that the water which fills the bottom of the narrow tube, and in which flies are drowned, is a secretion; it distils in drops from the inner surface of the young pitcher, before the orifice opens; yet, in this species and in *S. purpurea* (unlike *S. psittacina* and *S. variolaris*) there is little to hinder rain from falling in; and from this source I imagine most of the water comes which is found in old leaves. But it was only recently, and after a summer temperature was established, that any traces of the "sugary excretion" over the orifice could be detected. This made its appearance at first in the form of minute pearly globules, distinctly visible only under a lens; at length it forms flattened drops, and even patches, distinctly sweetish to the taste and viscid to the touch. I have not found any of this excretion at the orifice of the pitchers of *S. purpurea*, nor in *S. variolaris*, but I have not had good materials for observation in the latter case.

That the insects which abundantly fall or find their way into *Sarracenia* pitchers do not generally escape, but die and decom-

pose there, is obvious. That more commonly they do not perish by drowning in *S. flava* is equally clear. While all the lower and gradually attenuated part of the tube is filled with dead flies in our plants growing in the house, there is only a little moisture at the very bottom. One would hardly think that the fine and sharp deflexed bristles, which line the lower half of the tube only in *S. flava*, would greatly impede the return of a fly, they lie so closely against the wall of the tube. But I find that a house-fly, either large or small, when thrown into this lower part of the tube, is quite unable to get out, and there it perishes. Probably the advantage derived by the plant is equally secured whether their prey decomposes in the moist air of the cavity or in the water in which they are often immersed.

A main object of the present publication of this note is to ask observers to note whether any viscid secretion appears anywhere on the smooth portion, below the orifice of the pitcher, of *S. purpurea*. I am confident there is none upon the hood, which is wholly beset with unusually stiff deflexed bristles. I have had no full-grown specimens of this season to examine; and from analogy I should expect the sugary secretion, if any, to appear only in warm weather. A. G.

10. *Dionæa*.—The brief account of the action of this queen of fly-traps in Le Maout and Decaisne's Treatise, now becomes so much more conspicuous in its English dress, that it may be worth while to note, 1. that one does *not* find "on their upper surface two or three glands which distil a liquid attractive to insects." The scattered bristles on the surface of the trap, through which the sensitiveness is manifested, secrete no liquid. 2. Nor is it true that "when the insect is dead and all movement has ceased, the plates expand again and await a fresh victim." The trap does not open until, after several days, it has digested the soluble parts of its prey. This part of the work was probably prepared by Le Maout; and to several other statements in it may be extended the disclaimer appended to some of them by the English editor, viz: that they are opposed to all the established phenomena of plant-life, as known to English observers. A. G.

11. *Primitiæ Monographiæ Rosarum*, auct. F. Crépin: fasc. 2, 1872.—M. Crépin, one of the curators of the Royal Belgian Museum of Natural History at Brussels, and an able botanist, devotes a large part of this pamphlet of 130 pages to a revision of the Roses of the Herbarium of Wildenow. It is a separate issue from the Bulletin of the Royal Botanical Society of Belgium, May 11, 1872. It contains some matters of interest to us.

Under *Rosa Kamschatica* is an important discussion of the species and its whole history, identifying it with *R. rugosa* Thunb., to which also belongs *R. ferox* Lind., and the recent *R. Regeliana* of the *Illustration Horticole*. It is the Hedgehog Rose of the old English gardens.

Rosa blanda is also critically discussed, and on the whole *R. fraxinifolia* of Gmelin is thought to be a cultivated form of it.

Rosa Carolina L. The first and the sixth sheets represent this species; the rest, at least in part, belong to *R. lucida.*

Rosa parviflora Ehrh. All the specimens appear to be of this species, and the first sheet came from Muhlenberg.

Rosa lucida Ehrh., came also in part from Muhlenberg. Crépin concludes that it is a very polymorphous type, and the union of *R. parviflora* with it is apparently justified. But he is to consider the question in a special article on the American Roses.

Rosa nitida Willd. The first folio in the herbarium under this cover belongs to *R. Sinica* (*lævigata* Michx.), as had been already stated; the second, along with one specimen of the species in question (as cleared up by a specimen from the Botanic Garden, preserved in Link's herbarium), contains two which are thought to belong to *R. parviflora.* The question, whether *R. nitida* can be a form of *R. lucida*, is reserved.

Rosa gemella Willd. The first folio contains *R. Carolina*, a slender specimen. The second, probably the type of the species, Crépin supposes to be the "*R. blanda*, auct., non Jacq. R. Solandri," i. e., *R. blanda* Ait., to which the present writer referred it. It may be worth noting that it was not "Torrey qui avait examiner l'herbier de Willdenow," but his associate.

We solicit for M. Crépin copious specimens of all our wild Roses, in all their forms, and from every part of the country. To any who will thus contribute good materials for the monograph which he is engaged upon, Dr. Crépin will return critically named specimens of European Roses. A. G.

III. Astronomy.

1. *A Catalogue of Auroras observed from* 1776 *to* 1784, *in Labrador.* (Communicated by Cleveland Abbe.)—There has lately come into my possession a manuscript volume of meteorological observations made at Nain, Labrador, in 1776–1784, and at Okkak in 1778–1782. Portions of these observations have been long ago made use of by meteorologists, but the complete series has never, that I am aware of, been reduced; indeed its very existence has been known to but few. At present, in view of the interest taken in the questions relating to the secular periodicity of the aurora, I propose to give merely the dates on which such are noted in the journal of observations, omitting entirely the sometimes quite minute remarks of the observer, as to the characteristics of the individual appearances. The auroras are generally described under the heads of "Nord Licht," "Nord Schein," "Bogen Licht." In the latter case the directions and positions of the arcs are generally given.

The records were made by the following observers:

At Nain, by Samuel Liebisch, 1776 Oct. 1 to 1780 Aug. 31; by David Krügelstein, 1780 Sept. 1 to 1784 July 31, and a note on the aurora of 1784 Aug. 14.

At Okkak, by Jens Hafen, from 1778 Oct. 1 to 1782 Aug. 3.

It will therefore be seen that the record here given for Okkak is a continuation of that published by De la Trobe for the same place, for the years 1777 August to 1780 July, whilst on the other hand De la Trobe's records for Nain from 1777 August to 1780 August are probably identical with the corresponding portions of the observations by Liebisch, in the work now in my hands.

The list of dates of auroras is as follows: I have by a star designated those dates that are given in Lovering's Catalogues, on which auroras were recorded elsewhere.

Auroras observed at Nain, Labrador.

1779. Feb. 12;* Nov. 11.
1780. Sept. 1, 2,* 4,* 5, 6, 25, 26; Oct. 7, 21, 24,* 25, 29; Nov. 1, 15, 17, 25,* 28;* Dec. 1, 2, 17, 19,* 30.*
1781. Jan. 21;* Feb. 1, 22; March 3, 6, 11, 19,* 23,* 26, 29;* April 18; Aug. 17,* 24, 25,* 26,* 30, 31; Sept. 11, 12, 17, 20, 21, 26;* Oct. 15,* 18,* 19, 28; Nov. 9, 10, 11, 13,* 14,* 15,* 16,* 22 (7 a. m.), 25; Dec. 5, 6, 12* (6 and 7 a. m.), 15, 16,* 20.
1782. Jan. 2,* 16, 17; Feb. 2; Aug. 1, 13, 14, 22,* 30;* Sept. 7, 9,* 12,* 13;* Oct. 3,* 26;* Nov. 7, 18, 19 (7 a. m.), 19* (8 p. m.), 20 (7 a. m.), 20* (8 p. m.), 23, 25, 26,* 28.
1783. Feb. 4, 6, 24; March 7; April 23, 24;* Aug. 3, 14, 15, 19,* 22, 25; Sept. 3, 18, 23, 24, 26;* Oct. 1, 4, 12, 17, 23,* 25, 26,* 27,* 28, 29,* 31;* Nov. 2, 14,* 15,* 25, 27; Dec. 16, 18.*
1784. Jan. 9, 10,* 15, 19, 26, 28, 29; Feb. 9, 10, 19, 20, 21, 23;* March 3, 19,* 24; May 5,* 8 (?); Aug. 14.

Auroras observed at Okkak, Labrador.

1778. Nov. 23.
1779. March 24;* Sept. 4,* 5, 14,* 16, 17,* 18,* 19,* 20; Oct. 21; Nov. 3,* 7,* 11, 18.*
1780. Feb. 9.
1781. Oct. 28.

The comparison of these two records sufficiently shows that neither can lay claim to great completeness; the observer, Krügelstein, seems to have been specially on the watch for auroras, but it should be remembered that the period, 1780–1786, was one of the periods of great frequency of this phenomenon.

Of the 145 dates above given for Nain, 93 are not found in the extensive compilations of Lovering, and of the 17 dates for Okkak 8 are wanting in Lovering; of these latter, however, two are found in the record for Nain, leaving 99 new dates of auroras as the result of the present communication.

Washington, July 11, 1873.

2. *Meteors of Nov. 27th, 1872, at Teneriffe, Canary Islands;* by O. FREDERICA DABNEY. (From a letter dated American Consulate, Teneriffe, Canary Islands, May 11, 1873, to the Editor of Harper's Monthly, and communicated by him to this Journal.)—Reading lately in your Scientific record for March about the disappearance of Biela's comet and the meteoric showers of November 27, supposed to be fragments of it, it occurred to me that the following might be worth putting on record.

Rejoicing in an atmosphere celebrated for its clearness, our meteoric displays in November are always brilliant, and last year on the very night mentioned, 27th, no less than 500 were counted

in the space of about half an hour. On the night of the 29th, about half-past eleven, the family having retired and all lights being out, the rooms were suddenly brilliantly illuminated by an intense bluish-white light, which lasted for several seconds, brighter than moonlight, turning gradually red and then vanishing. As much as four minutes afterward, a report as if a large piece of artillery had been fired in the immediate neighborhood shook the house, and reverberated for some seconds in the surrounding mountains.

The cause of these phenomena seems to have been, from descriptions of those who observed it plainly, a large luminous body of conical shape, going with great velocity point foremost and drawing after it a long fiery train. It was observed from all parts of the island; observers on the north side reporting it as rising out of the sea and vanishing behind the peak; those on the south saw it vanish apparently below the southern horizon some minutes before the report.

The observers having been for the most part peasants and people of little education, it was difficult to obtain the truth from the marvelous reports made. The above, however, seems reliable, and the first part of the description is from personal observation.

3. *Observation of Tempel's Comet of Short Period;* by M. Stephan, Director of the Observatory at Marseilles. (From the Monthly Notices Astron. Soc., May 9.)—

May 1 at $13^h\ 17^m\ 24^s$ mean time at Marseilles; New Observatory.

R.A. $16^h\ 37^m\ 51^s{\cdot}59$ N.P.D. $103°\ 11'\ 52''{\cdot}3$.

The correction for parallax is not applied.

Mean position of Comparison Star, Weisse's 738 H, XVI, for 1873·0.

R.A. $16^h\ 39^m\ 39^s{\cdot}59$ N.P.D. $103°\ 6'\ 19''{\cdot}2$ Lal. 1. Bessel 2.

The comet was still very faint, though somewhat less so than on April 3.

4. *On Recent Estimates of Solar Temperature;* by James Dewar, Esq. (Proc. R. Soc. Edinb, vii, 697.) (Abstract.)—After referring to the recent discussion on the temperature of the sun, in which Secchi, Zollner, Vicare, Deville, and Ericsson have taken part, the author proceeds to group all the known methods of arriving at a knowledge of high temperatures under eight different processes. The following table gives the names of the physicists who have especially employed each process, together with the principle on which it is founded:

(1.) Guyton and Daniell, Prinsep, &c.—Expansion of Solids and Gases.

(2.) Draper.—Refrangibility of Light.

(3.) Clement and Desormes, Deville.—Specific Heat.

(4.) Becquerel, Seamens.—Thermo-Electricity and Electric Conductivity.

(5.) Bunsen, Zollner.—Explosive Power of Gases.

(6.) Newton, Waterston, Ericsson, Secchi.—Radiation.

(7.) Thomson, Helmholtz.—Mechanical Equivalent of Heat.

(8.) Deville, Debray.—Dissociation.

After treating of the great disparity of opinion regarding the temperature of the sun, the author proceeds to detail how it is possible, from the known luminous intensity of the sun, to derive a new estimate of solar temperature. This calculation is based on a definite law relating temperature and luminosity in the case of solids, viz., the total luminous intensity is a parabolic function of the temperature, above that temperature where all kinds of luminous rays occur. So that if T is a certain initial temperature, and I its luminous intensity, a a certain increment of temperature, then we have the following relation:—

$$T + n(a) = n^2 I.$$

The temperature T is so high as to include all kinds of luminous rays, viz., 990° C., and the increment a is 46° C. This formula expresses well the results of Draper, and I have used his numbers as a first approximation. It results from the above equation, that at a temperature of 2400° C., the total luminous intensity will be 900 times that which it was at 1037° C. Now the temperature of the oxyhydrogen flame does not exceed 2400° C., and we know from Fiseau and Foucalt's experiments that sunlight has 150 times the luminous intensity of the lime light; so that we only require to calculate at what temperature this intensity is reached in order to get the solar temperature. This temperature is 16,000° C., in round numbers. Enormously high temperatures are not required, therefore, to produce great luminous intensities, and the temperature of the sun need not, at least, exceed the above number. Sir William Thomson, in his celebrated article "On the Age of the Sun's Heat," says, "It is almost certain that the sun's mean temperature is even now as high as 14,000° C.," and this is the estimate with which the luminous intensity calculation agrees well.

5. *Meteor seen in Newfoundland.*—A letter from Henry H. Cleft to Prof. Henry, Secretary of the Smithsonian Institution, dated Harbor Grace, May 23d, 1873, states that on the 15th of May, at $8^h\ 5^m$ P. M., the writer saw a very large and bright meteor in the W.S.W., at an altitude of about 40°, moving rapidly to the westward, and leaving a long trail of yellow light after it. It burst at about $8\frac{1}{2}^h$ P. M. in the N.W. by W., 10° above the horizon; and the matter from it formed a coppery-red cloud below it of the shape of a comet's tail, which remained half an hour.

IV. Miscellaneous Scientific Intelligence.

1. *Flow of Water in Rivers and Canals;* by D. Farrand Henry, Chief Engineer Detroit Water Works, and late Assistant in the United States Lake Survey.—The greater portion of this pamphlet was originally published in the Journal of the Franklin Institute. It is mainly a discussion of the relative merits of the Telegraphic Current Meter, invented by the author, and used by him in his experiments for the determination of the outflow of the western lakes, and the double float used by Humphreys and Abbot in their experimental investigation of the hydraulics

of the Mississippi River. The general results obtained by the two methods of observation are also compared, and the points of disagreement considered. An Appendix contains a reply to the criticisms, published in the annual report of the Chief Engineer, U. S. A., to the Secretary of War for 1870, on the author's methods of current measurement, as set forth in his "Progress Reports, submitted to the Superintendent of the Lake Survey;" and a Mathematical Investigation on the use of floats in Guaging Rivers and Streams, by the distinguished mathematician, Prof. S. W. Robinson, of the Illinois Industrial Institute.

The author maintains that the measurement of sub-surface velocities by the method of double floats is liable to the following "principal causes of error," which do not affect measurements made with the telegraphic meter.

(1.) *The error of cross section;* which arises from the fact that "in order to ascertain the true mean area, it would be necessary to know the exact depth of the river past the whole base line; but generally it is considered sufficient to sound out two or three lines across the river, and take their mean depth, which, when the bottom is not perfectly regular, may differ considerably from the true mean depth."

(2.) *The pulsation of the current;* or, the existence, under all circumstances, of "an intermittent velocity, increasing and diminishing in accordance with some yet undiscovered law;" which may materially alter the result obtained by the double float, while all its irregularities will be accurately recorded by the telegraphic meter.

(3.) *The uncertainty of location* of the points at which the float crosses the upper and lower transverse section lines of the stream.

(4.) *Floating bodies move faster than the water in which they are immersed.* "This error is very small compared with the others."

(5.) *The upper float drags the lower.* "This error is also small and depends upon the relative size of the floats, and the velocity of the current."

(6.) *The effect of the current on the connecting cord;* which is to cause the cord to form a curve concave up stream, by reason of which the lower float is raised somewhat, and brought into a faster current. As a consequence the velocity determined by the float is in excess of the true velocity for the estimated depth, in which no allowance was made for the deviation of the connecting cord from the vertical line—the error increasing with the depth. In a series of comparisons of measurements made with the double float and telegraphic meter in the St. Clair River, the author finds, at the depth of 45 ft., the velocity given by the float to be 0·55 ft. in excess of that obtained with the telegraphic meter.

Our author joins issue with Humphreys and Abbot in respect to most of the general results obtained by them, as given in their Report on the Hydraulics of the Mississippi River.

(1.) *Maximum velocity.* The Mississippi hydraulicians place this, on a calm day, at $\frac{3}{10}$ the depth, and in general at depths varying with the force and direction of the wind, as represented by the following empirical formula,

$$d=(0{\cdot}317+0{\cdot}06f)r,$$

in which d is the depth at which the maximum current velocity obtains, f the force of the wind on a scale in which 10 represents the maximum force, and r the hydraulic mean depth.

The author reaches, from his discussion, the conclusion, that "in large rivers, we may consider the surface velocity in a calm time to be nearly the same as the maximum; while in narrow canals, especially when their sides are vertical, it may be considerably less."

(2.) *Form of velocity curve*, at various depths. Humphreys and Abbot adopted a parabola, with the axis horizontal, and at the depth assigned by the formula just given for the depth answering to the maximum velocity, as the best graphical representation of their Mississippi observations. Henry, on the other hand, fixes upon an ellipse, with its minor axis at the surface of the stream, as a closer approximation to the true velocity curve, on a calm day. He finds the parabola to be especially inaccurate when applied to the results of his own observations in the St. Clair River.

(3.) *Mean velocity.* One of the most important results obtained by the hydraulicians of the Mississippi was the establishment of a simple empirical formula connecting the mean with the mid-depth velocity, by means of which the mean velocity in the cross section of a stream could henceforth be deduced from mid-depth velocities observed at several points of the cross section. Henry maintains that the mean velocity obtains at $\frac{6}{10}$ the depth, and recommends as a still easier method of measuring the discharge of a stream, "to obtain the velocities at several points at $\frac{6}{10}$ the depth, and multiply the mean by the area of the cross section."

We must reserve, for the present, any decided expression of opinion relative to the several points at issue between our author and the distinguished hydraulicians of the Mississippi River. We are, however, ready to admit that he has supported his positions with signal ability, and weakened our confidence in important conclusions which we had supposed to be well established. There can be no question, also, that by the invention of his telegraphic meter, and the extended series of experimental determinations made with it, he has contributed materially toward the advancement of the science of hydraulics. His telegraphic meter is certainly far superior to Woltmann's meter, and every other form of stationary meter hitherto devised. The grave objection urged by Gen. Abbot, that the coefficient in the formula for deducing the velocity of the current from the number of revolutions of the meter, must of necessity be incapable of sufficiently accurate determination, seems to have been effectually answered by Henry, by showing that his coefficient has withstood the most

careful tests, applied to both surface velocities and velocities at depths of 40 ft. to 60 ft. W. A. N.

2. *Death by Lightning;* by Rev. HORACE C. HOVEY, M.A. (Communicated.)—A thunder-storm passed over Kansas City, Mo., on the afternoon of Sunday, June 15th, 1873, the results of which, so far as a single stroke of lightning is concerned, the writer has taken pains to verify by personal examination and the testimony of eye-witnesses.

When the storm arose a number of persons were walking on the broad platform of the amphitheater, in the fair-grounds adjacent to the city. The promenaders, either in ignorance, or negligence, of the laws governing the passage of electrical currents, sought refuge from the rain underneath the leafy branches of some oak trees which shade the locality. Under the tallest of these oaks, fifteen feet from the point where its trunk passes through the platform, and within three or four feet of the overhanging boughs, stood Miss Nora Ritenour and a young gentleman who had accompanied her to the grounds. An electrical discharge sought them out, on its way from the clouds to the earth. She was killed, and he was crippled; while the shock was felt for a hundred yards from the fatal point of impact, jarring buildings, and benumbing and prostrating human beings, so as to prevent spectators for a few moments from coming to the aid of the chief sufferers. When they did so, they found, to their horror, that the body of the young lady was actually undergoing combustion, making it necessary to extinguish the flames by pailsful of water. On inspecting the remains it was found that the first point of contact was the chin, where a red mark was left, as if by a violent blow. The rest of the head showed no external injury except that the hair was burned to a crisp. From the chin the electrical fluid sought the body, breaking the neck, and burning the breast and abdomen through and through. Its exit was by the right foot, leaving only a well marked groove along the limb; but tearing the shoe into shreds. Death must have been instantaneous, and was probably void of sensible pain, if one might judge from the placid features, and the natural and agreeable expression of the eyes.

It seems as if the stroke must first have traversed the adjacent oak; but the most careful examination discovered no disturbance of its branches, or injury done to its sturdy trunk. On leaving the body of Miss Ritenour, the entire discharge passed through the plank on which she stood, piercing it like a musket ball, the upper side of the perforation being smoothly depressed, while underneath it was jagged and enlarged. From the plank the bolt leaped two feet to a beam, along which its path was divided; being marked by a fissure leading in opposite directions to the two posts by which the beam was supported. These posts were of white pine, thoroughly seasoned, and about one foot in diameter. One was merely split from top to bottom, while the other was utterly splintered. To this latter piece of timber, boards had been nailed; and to each nail head, in passing, the electrical fluid paid most

discriminating attention, spliting the boards as if with the edge of an axe. The ground at the foot of these posts was not visibly disturbed. No traces of fire were to be seen on the dry, inflammable pine wood, although the living object, on which this memorable thunder-bolt concentrated its fury, was so fearfully burned.

3. *A new and ingenious American Move in the Game of Priority.* [We take this article from the Annals and Magazine of Natural History for July, and would add our full endorsement of its views. No copy of the circular letter referred to has reached us. Eds.]—The following circular letter, partly printed, partly written, which has just come to our knowledge, will, we think, somewhat amuse our readers:

"Buffalo Society of Natural Sciences, June 6, 1873.

"*To the Secretary of the ——— Society:* Dear Sir,—You are hereby notified that a paper entitled "Contributions to a Knowledge of North-American Moths," by A. R. Grote, has been read this evening before this Society, declaring that three new genera [*Litognatha*, *Meghypena*, *Phœcasiophora*] and nineteen hitherto undescribed species *Acronycta* 4, *Agrotis* 1, *Cloantha* 2, *Litognatha* 2, *Meghypena* 2, *Botis* 1, *Eurycreon* 1, *Phœcasiophora* 1, *Penthina* 3, *Graptolitha* 1, *Œta* 1] occur in the North American insect fauna (*whereof these Presents, to which the Seal of this Society is affixed, are evidence*), and that this Society considers the reading of the above paper as securing all rights to its author that he might acquire by publication.

"Mr. Grote's paper has been accepted by the Publication Committee of this Society for publication in its bulletin.

"Yours respectfully, Leon F. Harvey,
Corresponding Secretary B. S. N. S."

In characterizing this proceeding on the part of one of the youngest publishing societies in the world we are forced to cull a phrase from the slang dictionary; it is simply the "cheekiest" thing we ever remember to have seen. The use of legal phraseology in the words which we have put in italics has quite a peculiar charm, and will doubtless produce its due effect in causing entomologists in all quarters of the world to avoid trespassing on those unknown premises which have been formally handed over by "these Presents" to Mr. Grote by the Buffalo Society of Natural Sciences. It seems hardly credible that experienced naturalists, such as Mr. Grote at any rate is, should have even dreamed of adopting so absurd a course as this. Another favorite American dodge of printing descriptions of new species, with a date attached to them, for private circulation and not for sale, is bad enough, but it must yield the palm to the Buffalo invention.

4. *Transactions of the Academy of Sciences of St. Louis.*—No. 1 of Vol. III, containing 192 and xcviii pages, has just appeared. The articles of the number are—on the genus Yucca, by *G. Engelmann;* on a new genus of Tineidæ with remarks on the fertilization of Yucca, *Riley;* new N. American Hymenoptera,

B. D. Walsh; Atmospheric electricity, *Wislizenus;* Catalogue of earthquakes in 1871, *Hayes;* on the occurrence of iron ores in Missouri, *Gage.*

3. *A Dictionary of Science, comprising Astronomy, Chemistry, Dynamics, Electricity, Heat, Hydrodynamics, Hydrostatics, Light, Magnetism, Mechanics, Meteorology, Pneumatics, Sound and Statics,* preceded by an essay on the history of the Physical Sciences. Edited by G. F. RODWELL, F.R.A.S., F.C.S. 694 pp. 8vo, with numerous illustrations. (American edition. Philadelphia: J. B. Lippincott & Co.)—A good and convenient dictionary of the Physical Sciences, though unequal in the value of its articles.

4. *Physical Geography,* by ARNOLD GUYOT, author of Earth and Man. 124 pp., 4to, with numerous illustrations (Scribner, Armstrong & Co.).—Professor Guyot, one of the best of living physical geographers, has here prepared for academies and higher schools an admirable work on his favorite science. With a profound and comprehensive view of his subject, and of the relations of its several departments, he brings out in a simple way the general truths connected with it, without overloading his chapters with details. The excellent illustrations speak out boldly the facts or principles in view, and cover all branches of the science. There are also a number of large colored maps presenting the distribution of magnetic phenomena, volcanoes and earthquakes, temperature, winds, oceanic currents, course of tidal wave, rains, vegetation, etc. The volume should become a text-book in all our higher schools. We hope that Prof. Guyot may be enabled soon to finish the completer manual for our colleges and the scientific public at large, which he alludes to in his preface.

5. *American Association for the Advancement of Science.*—The twenty-second meeting of the Association will be held at Portland, Maine, and will commence on Wednesday, the 20th of August. Prof. Lovering of Cambridge is President for the year, and A. H. Worthen of Springfield, Illinois, Vice President.

6. *Royal Society.*—Prof. ASA GRAY has been elected Foreign Fellow of the Royal Society.

7. *Academy of Sciences of Paris, Session of July 7th.*—The order of the day was the election of three correspondents of the section of Zoology. At the first ballot, in which 44 members took part, the vote stood 38 for Steenstrup and 6 for Darwin; at the second, in which 46 voted, 35 for Dana, 10 for Darwin, with one blank; at the third, 48 voting, 35 for Carpenter, 12 for Darwin and 1 for Huxley. Whereupon Steenstrup, Dana and Carpenter were declared elected correspondents to the Academy.—*L'Institut,* July 9, 1873.

OBITUARY.

JOHN WELLS FOSTER died of rheumatism of the heart, at his residence in Hyde Park, near Chicago, on the 20th of June last, aged 58 years. Col. Foster's name became prominent in science by his connection with the "Geological Survey of the Copper lands of Lake Superior Land District," in 1850 and 1851, associated

with Prof. J. D. Whitney. Two Reports and an atlas embody the results of these explorations, the second volume being devoted to the iron region, together with the general geology. This is a work of high value in the development of American geology, both theoretical and practical.

Col. Foster was born at Petersham, Massachusetts, March 4, 1815, and graduated at Wesleyan University, Middletown. He served for a while in the Legislature of his native state. About 1854 he removed to Chicago where he has since resided. His later contributions have been chiefly his work on "The Mississippi Valley: its Physical Geography, etc."—various ethnological memoirs in the Transactions of the Chicago Academy, the American Association for the Advancement of Science, American Naturalist, etc.; researches on the "block coal" and iron ores of Indiana. The last and most important work of Col. Foster appeared at the very moment of his death, entitled "Pre-historic Races of the United States of America," a notice of which will appear in another number.

Henry James Clarke, Professor in the Amherst Agricultural College, died at Amherst, Mass., on the 1st of July. His labors as a zoologist, especially in those departments requiring difficult microscopic research, had placed him among the two or three first in the country, and given him a world-wide reputation. He was for a while assistant to Professor Agassiz in preparing his Contributions to the Natural History of the United States, and part of the embryological researches on the turtle are his work. Foremost among his several discoveries with the microscope is that of the true nature of the animal of sponges, till then misunderstood, the last paper on which subject by him appeared in this Journal for December, 1871. He was also the author of a work entitled Mind in Nature, based on structure and development in the animal kingdom, and containing many of his labored results, with illustrations from his own faithful drawings. He was always working, and full of enthusiasm in science, and also a most genial and excellent man.

Thomas Belden Butler, physician, jurist, and meteorologist, born in Wethersfield, Conn., Aug. 22, 1806, died in Norwalk, Conn., June 8th, 1873, in his 67th year. Judge Butler entered upon his legal studies after practicing medicine for some years following his graduation in the Yale Medical School, and enjoyed high repute as a jurist. He was a student in many collateral branches of knowledge, especially in agriculture, mechanics, and meteorology. He was the author of "The Philosophy of the Weather" (1856), and of "A concise analytical and logical development of the Atmospheric System: Hartford, 1870." He was chosen Judge of the Superior Court of Connecticut in 1855, and in 1861 of the Supreme Court, of which he was made Chief Justice in 1870.

De Verneuil, the eminent geologist of France, to whose labors the progress of geological science in America, as well as in Europe and Asia, is profoundly indebted, died at Paris on the 29th of May, at the age of sixty-eight years.